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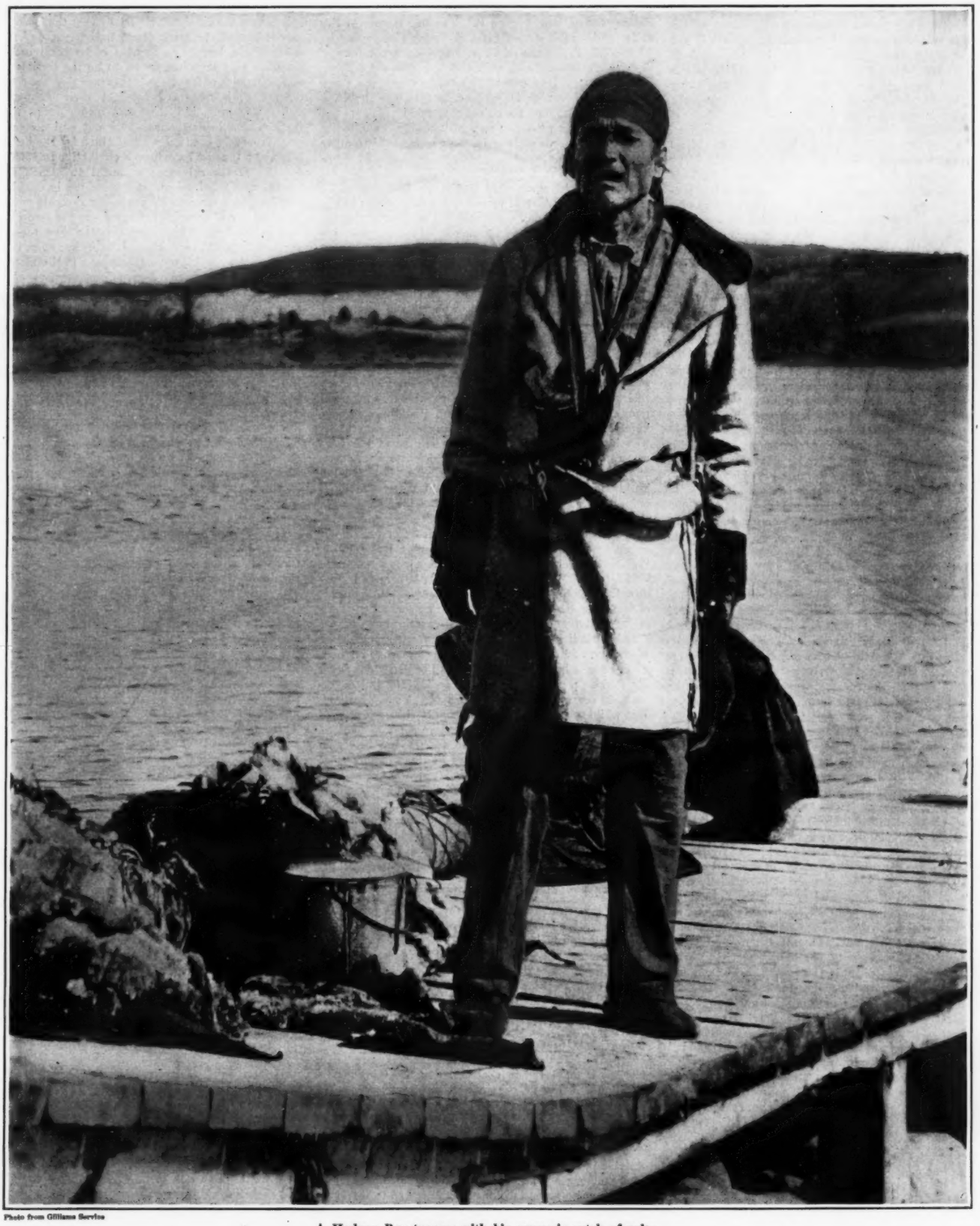


Photo from Gilliams Service

A Hudson Bay trapper with his season's catch of pelts

THE FUR TRADE OF THE UNITED STATES—[See page 24]

The Biological Aspects of Warfare*—I

Instincts and Restraints that Affect Human Relations

By Harry Campbell, M. D. Lond., F. R. C. P. Lond., Physician to the West-End Hospital for Nervous Diseases, London

THE FUNCTION OF THE COMBATIVE INSTINCT

From the biological standpoint the combative instinct is to be regarded as a normal mental attribute, not as a quality to be condemned offhand as something which the world would be all the better without. That it has existed for a useful purpose is shown by its universality among all but the lowest animal organisms and by the fact that special weapons of offense and defense in the shape of horns, tusks, claws, and the like have evolved to give effect to it. Some measure of combativeness is obviously necessary for all the vertebrates and many of the invertebrates in the struggle for existence, for a creature without some self-assertiveness, some show of fight, would be at a distinct disadvantage in that struggle. The primary object of this instinct is to enable an animal to get the better of a rival by direct encounter. The emotion attaching to it is anger—the most violent, be it noticed, of all the emotions. This emotion, unless controlled, causes the combatant to assume a ferocious aspect—to show the teeth, erect the hairs, and to utter terrifying sounds, all with the object of cowing the opponent—while at the same time it has the effect of liberating the flood of muscular energy needful for the ferocity of onslaught which makes for success. Although unbridled rage is helpful in fight among the lower animals, needless to say it is the reverse of serviceable in the deliberate fighting of man against man, as in boxing and fencing, for here anger interferes with those cautious methods of attack and defense which are essential to success. To lose one's temper in fighting of this kind may be to lose the fight. With this reservation it is curious to note the close kinship between the combatant instinct of man and of the lower animals. The untamed man, when enraged, assumes in very truth the aspect of the tiger; he puts himself in a threatening attitude, frowns, glares, rolls his eyes, grinds his teeth, snarls, growls, or even roars—thus instinctively seeking to strike terror into his opponent. The raising of the voice in anger is manifestly akin to the roar of the angry carnivora. Darwin has pointed out the connection between the human sneer and the snarl of the angry dog, and I have myself seen a refined woman in a transport of spite lift her upper lip and show her teeth in a manner absurdly like an enraged beast. But nothing shows more clearly the essential identity of the fighting instinct in man and the lower animals than the way in which a child, soon after it can toddle, will rush at the object of its passion and proceed to bite and scratch, *i. e.*, to use teeth and claws, as any of the carnivora might. It would be interesting to know how far the grimacing habit of children is related to the combative instinct. A child protrudes its tongue and contorts its features in order, it would seem, to express dislike and defiance.

The primary object of anger, rooted as it is in the fighting instinct, is to prompt to combat. This is its natural goal. The emotion may, however, fail to realize itself in the natural way, owing to the operation of restraining influences. Such a one is fear—in the case of the lower animals practically the only one. In the case of man, other inhibitory influences come into play. The normal civilized man, even when in a tempest of passion, is able by an effort of will, to restrain himself from venting his rage by the primitive method of personal assault.

Now, among the causes of anger, pain, especially when it can be referred to an external source, takes a prominent place. This, we may suppose, is because among the lower animals pain is frequently caused by the attack of another animal. The animal attacked is roused by the pain inflicted to retaliate upon the aggressor, and every additional pang sustained in the course of the encounter intensifies the fury which makes for success. In order that it may excite to fury the pain must not, however, be too intense, for in that case it may have a paralyzing, numbing effect, robbing the combatant of courage and prompting to hasty retreat. This cowing effect of pain is made use of in training unruly animals, human and other.

The tendency to retaliate upon an object causing pain does not always display itself in a rational way. There is a disposition to vent rage, *e. g.*, upon the innocent bearer of bad news or even upon inanimate objects: thus a man who hurts himself against an object may have an irresistible impulse to kick that object, just as a dog bites at the stick which is lifted against him; similarly, an undisciplined person may in a transport of passion relieve his feelings by smashing all breakable articles within reach.

The effects of anger which realizes itself in actual assault being to injure and to inflict pain, the question arises how far the assailant derives satisfaction from the injury and pain which he inflicts. Here we find a striking contrast between man and the lower animals—and not to the credit of the former. The sub-human animal has no conscious desire to inflict pain upon the object of its rage; it is just impelled by blind instinct to make a destructive onslaught upon it. The like is true of the child who scratches and bites the person annoying it. The child—the young child at least—does not form a definite idea of inflicting pain and then proceed deliberately to put it into effect. When, however, the stage or self-consciousness is reached, anger may beget a definite desire to hurt the object of it, and if this does not find vent in the primitive way of inflicting some bodily injury, it may seek satisfaction by causing pain in other ways, as by taunts, jeers, scoldings, or long and deep-laid plans of revenge.

Here we touch upon what is perhaps the basest of all vices—cruelty. A cruel person is one who exults in the pain, mental or bodily, suffered by another. Cruelty has its basis in anger (and thus is related to the combative instinct), though there is a cold-blooded form of cruelty which may be enjoyed without any obtrusive feeling of anger. Cruelty, implying as it does self-consciousness—the ability to realize the feelings of others—is essentially a human attribute. Children who impale frogs and eviscerate flies cannot be said to be cruel, for they know not what they do. Nor are the lower animals cruel, seeing that they are wholly unconscious of the sufferings of others. Thus the charge of cruelty against the carnivora is unjust. These animals generally destroy their victims outright and in the rare cases (*e. g.*, cat and mouse) where they prolong the suffering they have no knowledge of the pain they are causing. When therefore, we stigmatize the conduct of the cruel man as "brutal," we wrong the brutes. The animal which attacks another, and in so doing causes pain merely responds to a blind unthinking instinct; but man, proud man, who looks before and after, is able to realize and take pleasure in the pain he deliberately, and by subtle means maybe, sets out to cause. It is clearly absurd to speak of his conduct as "brutal." Rather should we call it devilish, the Devil usually being credited with a goodly share of intelligence. We must cease to libel the brutes by designating the basest acts of man as brutal. As a matter of fact, they cannot be charged with non-moral conduct, seeing that they are devoid of self-consciousness.

Spite, vindictiveness, and actual revenge are all forms of cruelty, and thus are rooted in the combative instinct, and so too is hatred, which is a kind of persistent anger directed on a particular object. Irritability and querulousness are minor manifestations of the same instinct. But while some of the worst of man's vices are derived from the fighting instinct, so also are some of his best qualities. The primitive desire to get the better of another has found expression not in violence alone, but in that hearty spirit of emulation which is essential to progress, and anger in the form of righteous indignation has through the ages moved men altruistically: we feel a touch of the sufferings of others and some measure of the anger and the impulse to retaliate which actual experience of these sufferings would excite in ourselves. Here, indeed, is the source of all our reforms.

THE EVOLUTION OF THE COMBATIVE INSTINCT

Two important factors have favored the evolution of the combative instinct: (1) the reproductive instinct, and (2) the struggle for food.

1. Among polygamous species the males, as is well known, fight furiously for the possession of the females. To aid them in these encounters they are provided with special weapons which (as in the case of the horns of the stag) may only attain full development, and only remain fully serviceable, at the breeding season. At this time, too, animals, otherwise docile, may become dangerously aggressive. In the case of the female, also, the combative instinct is employed in the service of the reproductive function. A cat in charge of her kittens will, when danger threatens them, be roused from the tender maternal mood to sudden fury in their defense. Here we see the most opposed of all emotional states—love and anger—alike called forth at the bidding of the reproductive instinct. Let us not fail duly to appreciate the fact that one and the same individual is endowed with such opposite potentialities. I shall return to this point presently.

2. The combative instinct is helpful in the food struggle. How close is the relation of the one to the other is shown by the effect of hunger: the hungry beast is wont to be savage, and the hungry man is proverbially apt to display, in an attenuated form no doubt, some of the ferocity of the hungry beast; after a good meal he subsides into an amiable, pliant mood. Even animals usually gentle scramble and fight among themselves for food, but it is among the carnivora especially that the food struggle has developed the spirit of combativeness, and it is, as we shall see, largely on account of his carnivorous propensities that man has grown to be the terrible fighter which in point of fact he is. It is true that the carnivora do not ordinarily need to fight their comparatively defenceless prey, but there can be no doubt that the instinct that leads them to seek out and destroy their prey is largely based upon and aided by the combative instinct. It must have been a combative impulse which led the first carnivorous mammal to attack its first victim, and this instinct must be of use in enabling the assailant to overcome an unusually doughty opponent. As a matter of fact, all the carnivora are ferocious. It may be pointed out in passing that the appearance of the carnivora upon the scene has probably had some influence in generating a spirit of combativeness in the species they prey upon, in that some degree of pugnacity is of service to the latter in helping them, especially if acting in combination with others, to resist their assailants.

The fact that carnivorism makes for ferocity and develops the fighting instinct has this interest—that man is himself carnivorous. Indeed, in the matter of slaughter he leaves all other animals far behind. He is the arch-slaughterer—*facile princeps*. Since the time the pre-human ape took to hunting he and his human descendants have wrought ruthless havoc among the lower animals, and at the present day man not only hunts them, but breeds them for the express purpose of destroying them, chiefly for food, partly for amusement. Many a person of gentle nature would be amazed and horrified were he at the end of a long life to see *en masse* the hecatombs of living things done to death on his behoof.

I have already alluded to two sharply contrasted aspects of the carnivorous nature. It is a fact calling for special note that in spite of the intense ferocity of the carnivora their emotional nature has its softer side. The most ferocious carnivorous mother lavishes upon her young a devotion not always to be found in the human mother. A vixen will wear herself to skin and bone in the nightly hunt for her cubs, and returning to them "red in tooth and claw" immediately fall into a purring mood. Her victims excite in her the ferocity to shatter and destroy; her young, the tenderness to shelter and protect. To the one she is the embodiment of terror and destruction; to the other of gentleness and protection. These facts are pregnant with meaning for us. They remind us that the emotional nature of carnivorous man also is compounded of extremes. He, too, has his ferocious and his tender side. The ferocious element in him is the source, as we have seen, of some of his ugliest traits, such as cruelty and revenge, while ultimately it stands for the crude egoistic principle that "might is right." The tender element, on the other hand, is the fountain of all his virtues. The great lesson to be learnt from a consideration of this duplex emotional nature, this taint of the devil, this touch of the divine, is that either side may be cultivated at the expense of the other; the average person may, according as he has been nurtured, develop into an unmanageable hooligan, fearing neither God nor man, or into an entirely respectable, law-abiding citizen.

The differing attitude towards one another of the carnivorous mother, her prey, and her cubs, is further instructive in that it affords an example of the strong sympathies and antipathies which are displayed by animals, not only between members of different species, but even between those of the same species and more especially of the same sex. Much might be written on this interesting subject. It must suffice here to draw attention to the decisive influence of personal likes and dislikes in the conduct of human affairs. Dislikes, often amounting to virulent hatred, operate antisocially, conducing as they do, not to peace and goodwill, but to bickerings and bloodshed.

When we read of the terrible happenings in the present war we begin to wonder how far civilized man differs in his essential nature from early man in his most savage state. Though man's moral nature has doubtless undergone development since primitive times, he still retains much of the wild beast within him. We are apt to forget

*From *The Lancet*.

how very much the individual is, both intellectually and morally, the product of his environment. What would the modern civilized man be, intellectually considered, were he not, as regards his knowledge, the heir of all ages? A modern European child brought up under the same conditions as palæolithic man would probably achieve no more in the intellectual sphere than did he. We too readily forget that a man's intellectual powers remain merely potential in the absence of the conditions needful to call them forth. This explains how it was that during the long palæolithic age man made little or no advance in knowledge, while during the last century he has more inventions to his credit than during his whole previous career.

Applying the same principle to man's moral nature, we shall the better understand how greatly that also is influenced by his upbringing. While the innate moral leanings of civilized man are doubtless superior to those of the savage, yet it can hardly be denied—so great is the influence of nurture—that an average European brought up among savages would take quite naturally to their most revolting customs, and, on the other hand, that an average "savage" reared in a European community would make a very respectable and peace-loving citizen. Let us, then, ever remember that man, like the tiger, has two strongly contrasted dispositions—the combative destructive, and the tender altruistic—at the same time not forgetting that each of these dispositions is, within due limits, an essential attribute of the normal man. The man who has no kind of fight in him, who is prepared to take any affront lying down, who is incapable of being stirred to righteous anger, is but half a man, and one wholly devoid of altruistic feeling is equally abnormal. I say that each of these dispositions is needful within due limits. The qualification is necessary, for either may be developed to a harmful degree. The combative element may be developed to the point of destructive criminality; the tender altruistic feelings may acquire such intensity as to render life intolerable—the hyper-altruist may be undone by the defects of his virtues. What, however, I desire to drive home is the fact that, taking any average individual, whether he shall be an outlaw or a decent law-abiding citizen will depend entirely upon which of the two sides of his nature shall be nurtured. Nevertheless, and in spite of all this, the most careful upbringing is powerless to change man's normal nature to its very depth, to eradicate all potentiality towards the primitive savage. Often the effect of education is but to cover with a thin veneer of moral polish the savage beneath. That the primitive passions do but slumber in the civilized man is shown not only by the savage orgies which are wont to occur in wars, revolutions and outbreaks of mob violence, and by the murderous activities of the apache, but even more perhaps by the calculated, cold-blooded cruelties of the Middle Ages, as displayed, *e. g.*, by the agents of the Inquisition, and in the devilish treatment meted out to prisoners. Let no man suppose that human nature undergoes any essential alteration in the course of a few generations. What civilized man was in the Middle Ages such is he in his essential nature today. It is therefore wisest to regard the young human as compounded of the same two opposite dispositions as are found in the tiger, and as being in large measure a wild untamed creature, needing to be broken in and put through a painstaking training from earliest years if he is to be fitted for the difficult duties of good citizenship.

It is not, of course, possible by education to force everybody into exactly the same mould. Individual traits, good, bad and indifferent, will show themselves under any system of moral training. Taking any number of persons, we may arrange them in a series according to their innate moral proclivities, beginning with the moral idiot, whom no education can greatly better, and ending with the moral genius who, with very little guidance, blossoms into the saint. Numerous individual differences of character will be met with in such a series, many of which are only discernible and understood by intimate acquaintances, if, indeed, by them. Many a potential murderer, many a man capable of carrying out the infamies of the Inquisition, passes in society as a right good fellow and is received as a welcome guest, while many a man of kindly nature is judged harshly simply because he does not wear his heart upon his sleeve.

THE INFLUENCE OF MAN'S HUNTING CAREER AND OF TRIBAL LIFE ON THE EVOLUTION OF THE FIGHTING INSTINCT

Let us now inquire how it has come about that man has acquired his slaughtering propensities. The fact, as fact I believe it to be, that it was the search after animal food which caused our ape-ancestor to abandon the forest, suggests that he already had a good deal of fight in him, as well as enterprise, when he entered upon his hunting career and came to compete with the carnivora for animal food. The period which elapsed between the abandonment of an arboreal life and the attainment of human-hood, say, when tribal life was fully established, was one in which the evolving man steadily increased in skill as a hunter and in which his combativeness underwent steady evolution, for success in the hunt demanded not only skill and cunning, but courage and the combative instinct.

Incidentally I may here reiterate my conviction, already advanced in this journal,[1] that it was the conditions entailed by a hunting career which brought about the evolution of the pre-human ape into man. For observe the curious situation—assuredly one of the most eventful and dramatic in the whole of man's evolution—when this creature took to hunting. Here was a being lacking the stereotyped equipment for slaughter, instinctive and anatomical, of the carnivora, but gifted with an intelligence surpassing that of any other creature, and endowed with *prehensile hands capable of giving effect to that intelligence*. It was a situation in which intelligence counted in the life-struggle as it had never counted before, and it inevitably led to the evolution of a higher type. This agile, intelligent, hand-endowed precursor of man was compelled to rely upon his intelligence in hunting his prey; for blind instinct he had to substitute strategy; for natural weapons, weapons made by hand. Once the pre-human ape started on his career of intelligent, as against instinctive, hunter, he began a struggle in which it was inevitable that a higher and ever higher grade of intelligence should continue to evolve by natural selection until sufficient mental capacity had been attained to render its possessor supreme in the chase.

When tribal life with its attendant inter-tribal warfare was established—a warfare in large measure at least for the possession of hunting grounds and districts rich in valuable vegetable foods—the evolution of the fighting instinct received a further stimulus, for the more courageous and warlike tribes tended to wipe out the less courageous and more peaceful.

Here it is necessary to point out that from the evolutional standpoint inter-tribal and modern warfare present a striking contrast. In the former not only do all, or practically all, the men of the tribe take part in the fight, but the percentage loss of the vanquished is generally much greater than that of the conquerors. Defeat may, indeed, mean the partial annihilation of the vanquished, if not after a single battle, at any rate after a process of guerilla warfare waged it may be through years. Thus the effect of inter-tribal warfare has been to further the evolution of the bravest, and in even greater degree (I may here add) of the most intelligent, tribes. But while, as I have elsewhere insisted,[2] inter-tribal warfare has furthered man's psychic evolution, civilized warfare is eugenically hurtful—for whereas individual tribes can annihilate one another, this is not possible with modern civilized nations. When two such nations engage one another in war, the percentage mortality for each entire nation is much the same and has little or no ultimate effect upon the proportionate population of each nation. The effect of warfare between modern civilized nations cannot therefore lead to the survival of a superior nation at the expense of an inferior one. Its effect is rather to work against evolution by causing the elimination of the best physical types (the First Napoleon is said to have taken two inches off the stature of the French nation) and of those who display the most courage and daring. Were civilized warfare carried on by voluntary armies alone the effect would be to cause a disastrous elimination of the bravest; I say disastrous, for assuredly courage is one of the noblest attributes of man. Even with compulsory service a large proportion of the least brave manage to avoid the danger zone.

With the establishment of inter-tribal warfare the fighting became the most terrible the world had yet known. No longer prompted by blind instinct and carried on with nature's weapons (teeth, claws, horns, and the like), in which victory was generally to the physically strongest, it became a fight with hand-made weapons, wielded warily and with deliberation, a fight in which not only courage but intelligence played a part such as it had never played before, for it was intelligence which fashioned the weapons and directed their use and which planned the organized attack.

The chief factors in the evolution of the fighting instinct in man have been the reproductive instinct, the search after animal food, and inter-tribal warfare. The ultimate effect of these factors has been to make man of all vertebrates the most inveterate fighter. Not only does he wage incessant warfare on other species, destroying infinitely more than any other vertebrate, but he also fights persistently with members of his own. Except in the struggle of rival males for the possession of the female, there is comparatively little intraspecimen fighting among the vertebrates: whether gregarious or otherwise, members of the same species live together in a comparative harmony. Man, on the other hand, from the dawn of the tribal period up to the present time, has made incessant warfare upon his fellows.

When we come to compare warfare as waged between civilized nations with primitive inter-tribal warfare we find that far from its terrors being mitigated they are becoming greater than ever. Human ingenuity has so exhausted itself in the endeavor to devise the most deadly methods of destruction that it is difficult to imagine anything more terrible than those employed in the present war. It is true that modern warfare has at various epochs been robbed of some of its terrors by the spirit of chivalry, though it must be confessed that, much as we may commend that spirit, there is something incongruous in two armies setting about to kill one another in a gentleman-like way, with perfect willingness to be good friends after vast numbers of their comrades have been mutilated and slaughtered. But even among the most chivalrous foes some degree of devilry and frightfulness is apt to creep in, and if the spirit of chivalry is lacking on the one or other side, then, indeed, is man seen at his worst, as one compared with whom the famished tiger maddened with blood lust is as an innocent babe.

[TO BE CONTINUED]

[1] Man's Metal Evolution, Past and Future, *The Lancet*, 1913, 1., 1260, 1333, 1408, 1473. [2] Ibid.

The Value of Ignorance

WE doubt not that there may still be found in Sheffield old men who, in defiance or ignorance of the teachings of metallurgical science, hold that in the river Don there reside properties which give Sheffield steel its world-renowned quality. So strong was that belief that not so very many years ago the waters of the famous river were borne in vats to America for the steel makers of the New World. Faiths of the kind are not easily overthrown, and in an industrial city like Sheffield, with its hundreds of little masters to whom the new knowledge percolates slowly, if at all, they endure long. Science may lengthen its stride, faiths may be shaken by research, the beliefs of one generation may be transmuted by the chemist, the physicist, and the metallurgist into the legendary lore of which future poetry is made, but many a man still holds by the belief of his fathers, and his father's fathers; and not any college of scientists, with its Vimy Ridge charge of explosive knowledge, shall make the tiniest rift in his splendid ignorance. And why should it? Was it not on the world's ignorance and Sheffield's faith in the waters of the Don that England's reputation for cutlery was founded? Sheffield is not alone in this kind of faith. Vienne, on the river Gère, a tributary of the Rhone, claimed for its stream the self-same properties. Its waters, Monsieur Bouchayer stated in a paper read at Grenoble some months ago, and printed in the last issue of the *Revue de Metallurgie*, were even regarded as sacred, for "La secrète vertu qu'elle a pour la trempe du fer et de l'acier a quelque chose de divin, surtout dans une nation guerrière." Like Sheffield, Cienne, the ancient capital of the Gaulois, owed its prosperity to the marvelous waters of the Gère. Many an industry has flourished on the maintenance of beliefs of the kind, and one cannot be surprised that they are not readily relinquished by peoples to whom they have brought fortune. Even to this day they are accepted. Can we forget how deeply engrained was the faith that only in Bavaria could be made certain kinds of glass, till Professor Jackson overthrew it by the industry of a few months? When it is to the benefit of a district to believe that Providence has endowed it with exceptional qualities, it is little wonder that the door is held fast against the intrusion of a science that would explode the precious fallacy.—*The Engineer.*

Zinc Alloys

IN Europe there are now in successful use some new alloys of zinc with the metals of the iron group such as tungsten, cobalt and nickel, or gain with aluminium, and these alloys are said to replace the best qualities of bronze made with copper and zinc. The metals of the first group, tungsten, cobalt or nickel, are added to zinc in the proportion of 2 per cent, and aluminum is added at the rate of one to eight per cent. These metals are put in the crucible at the same time as the zinc and are placed underneath the latter. The crucible is then placed in a furnace and heated to the melting point of zinc, then the heat is continued until it reaches about 950 degrees. In this case the zinc slowly dissolves the other metals. The resulting alloy is said to be of a brilliant white color, and it flows very well.

Color of Pure Copper

THE work of a Swiss investigator suggests that absolutely pure copper may have a light grey color like that of most other metals, since it is found that copper which has been ten times distilled in vacuo has only a pale rose color, while the yellow color of gold becomes much lighter under similar treatment.

The Nature of Sun-spots*

And Studies of Their Life History

By Rev. A. L. Cortie, S.J., F.R.A.S., Stonyhurst College Observatory

A SUN-SPOT consists generally of a large dark area called the umbra, in which at times darker patches can be detected, called nuclei. The umbra is surrounded by a filamentous area of much greater extent, in wavy and broken patches, called the penumbra. Between the umbra and the penumbra is a boundary region of lighter hue, forming the inner edge of the filaments of the penumbra. Photographs on a large scale, showing much detail, as those for instance taken by Father Chevalier at the observatory of Zo-Se in China, confirm the reality of a real increase in light at the interior border of the penumbra of a sun-spot. But they also show that this maximum of luminous intensity does not occur at the extremity of the filaments. These extremities are not in the form of luminous club-heads projecting over the umbra, as figured in Langley's hypothetical drawing of a typical sun-spot, but of tapering points, which curve over towards the umbra, and diminish gradually in brightness. The arrangement of these filaments is in the form of undulating layers, lighter in the regions that are more raised, and darker in those that are at a lower level. A really large sun-spot is of enormous size. For instance, the group, easily visible to the naked eye, which crossed the sun's disk between February 4 and 15, 1917, in south latitude 15.6° and longitude 10.2°, extended over 18° in longitude and 6.5° in latitude, while its surface area was 26 units, in terms of the 1/5000 of the visible disk. Roughly, this disturbance affected an area of 3,500 millions of square miles, exceeded indeed by the spot of February 7th, 1905, which covered 3,800 millions of square miles.

The life-history of a group of sun-spots generally follows a definite progression of changes. At first a few small spots appear in bright compact faculæ, or luminous white clouds, the faculæ preceding the appearance of the spots. These spots then coalesce into two main spots, a leader or western spot of the group, with a trailer or eastern spot, with many subsidiary spots bridging the gulf between the two main spots of the group. It is in this complex region between the spots that, in the earlier days of the life-history of a group, the greatest display of energy takes place. In this region spectroscopic observations show many reversals and distortions in the hydrogen lines. Meanwhile the faculæ are still very bright and cling to the spots. The subsidiary spots bridging the gulf between the leader and tail spot will first disappear. The tail or following spot will next break up, leaving the leader spot to attain the comfortable rotundity of middle age. Finally, this spot, growing ever smaller and smaller, will disappear as a few insignificant dots. The faculæ, which in the early days of the life of the spots clustered round the group in dense luminous clouds, will extend in branching lanes to cover an immense area of the solar surface.

From a detailed study of some 3,500 drawings of solar spots made at Stonyhurst, it was possible to divide all spots into five normal types. But the chief type, of which the others are but phases, was found to be the double spot formation. These groups have subsequently received from Prof. Hale the name of bipolar groups, and they exhibit opposite magnetic polarity. In the northern hemisphere and in middle solar latitudes, the direction of rotation for the preceding spot or western spot is counter-clockwise, and for the eastern or following spot clockwise. This direction of rotation corresponds in the preceding spot to that of a terrestrial tornado. The opposite direction obtains in the southern hemisphere, as is the case also in terrestrial tornadoes. But in spots in high latitude these directions are reversed.

Sun-spots appear to be dark, the umbræ and particularly the nuclei seeming to be very black, but in reality they are intensely bright—far brighter than any terrestrial source of illumination. They are composed of uprushes of metallic vapors, in which vanadium, titanium and iron are very evident. The rapid expansion and consequent cooling relatively to the bright solar surface cause them to absorb the solar light, and hence to appear dark. The temperature of the sun's surface is about 6,000 degrees on the absolute Centigrade scale, and that of sun-spots, as is indicated by a lowering of temperature sufficient to allow of the formation of chemical compounds, such, for instance, as titanium oxide, magnesium hydride, and possibly superheated steam, is about 3,500 degrees on the same scale. Hence they exercise an absorbing effect on the higher temperature vapors of the solar core.

In the year 1769 Dr. Wilson of Glasgow broached the idea that sun-spots were depressions in the solar surface. His demonstration was founded upon the appearance of the penumbra of spots, seen in perspective, as the spots travel from east to west across the visible solar hemisphere. When the spot is near the east limb, the penumbra only appears on the side turned towards the limb, and appears to be wanting on the other side. As the spot approaches the center of the disk the westerly edge of the penumbra gradually comes into sight. As the spot moves towards the west limb carried round by the rotation of the sun, the eastern part of the penumbra begins to disappear, so that when it is near the west limb, the western side of the penumbra is alone seen. The interpretation of these phenomena is that the spot is a saucer-like depression, with the umbra corresponding to the bottom of the saucer. But there are relatively few round symmetrical spots which can be observed as tests of this theory. Moreover, when the spots are very near the sun's limb, the penumbræ are not seen at all, but only a foreshortened dark line, presumably representing the umbra. The umbra also, when a large spot is on the limb, seems to block out the view of the edge of the sun, and would be better described as an elevation above the level of the general surface of the sun, than as a depression below it. This was noticeably the case when the big spot of February 15, 1917, was crossing the sun's western limb. Visually a sun-spot is a shallow depression represented by the penumbra, in which rises an elevation seen as the umbra.

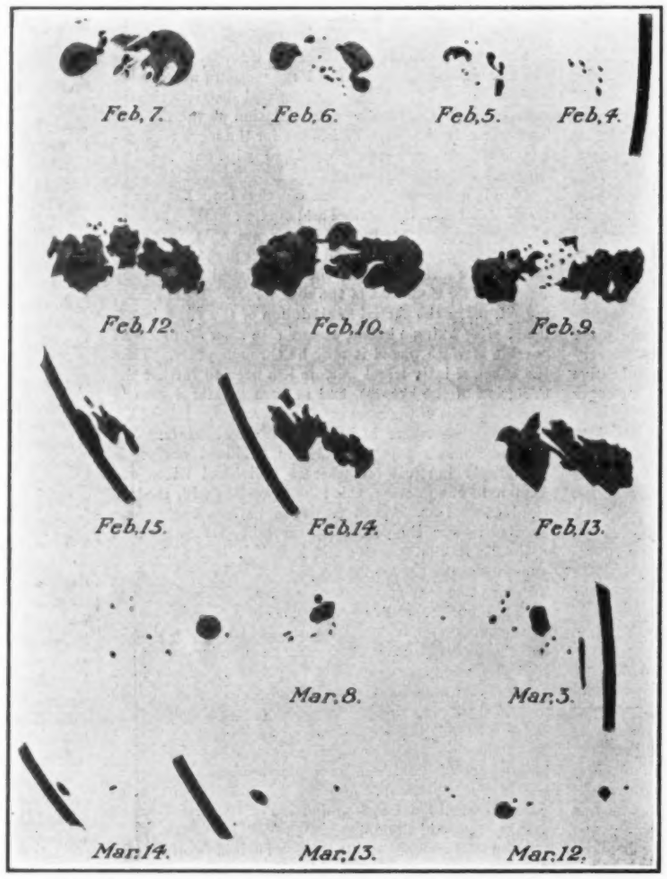
There are relatively very few spots in which a gyratory or cyclonic motion can with certainty be detected. Nevertheless there are such instances observed, as for instance the rotation of the umbra and penumbra of a spot around a nucleus described by Dawes, who recorded in one case a rotation of 100 degrees in six days, and on December 23, 1851, observed in a spot a rotation of 70 degrees in one day. As observed at Stonyhurst, the sun-spot of April 16-21, 1882, revolved through 90 degrees in four days. From his spectroscopic observations of movements in the penumbræ of spots, Mr. Evershed also comes to the conclusion, that if a rotatory movement exists in some spots, it is not a constant and regular feature of spots. Yet as demonstrated by observation some spots, by the swirling appearance of their umbra and penumbra, vividly suggest a cyclonic or rotatory motion in the spot.

A spectro-heliograph is a modification of the spectroscope, by which it is possible to photograph the sun's surface and envelopes in monochromatic light, either for instance in the red light of a hydrogen ray, or the violet light of a calcium ray. Also it is possible to photograph the clouds of calcium and hydrogen which exist above and around sun-spots at different levels, so that a picture may be obtained of the sun in light corresponding to relatively low-lying calcium, and to calcium at a higher level. These spectro-heliograms, as they are called in calcium light, show that a sun-spot is covered and surrounded by extensive clouds of luminous calcium vapor. Many photographs of these flocculi, for so they are named, both in calcium and in hydrogen light, have been made by M. Deslandres, and by Prof. Hale. It is found that the calcium flocculi, which may be likened to the cumulous clouds in the earth's atmosphere, exhibit no well-defined linear structure. But the hydrogen flocculi of the higher regions of the solar atmosphere exhibit a very definite structure, and appear, in relation to the sun-spots they surround, as cyclonic whirls, right-handed or left-handed as the case may be, which are highly suggestive of lines of magnetic force. On June 3, 1908, a great cloud of hydrogen, which had been photographed earlier on May 29th and succeeding days at Mount Wilson as hanging on the edge of a vortex structure, was suddenly sucked into the spot at a velocity of about sixty miles a second. Hence we derive the genesis of the idea, that sun-spots are analogous to tornadoes or water-spouts in the earth's atmosphere, with the trumpet like end upwards.

Let it be remarked, however, that these observations, and the deductions from them, concern only the higher regions of the gases and vapors above a sun-spot.

When a sun-spot is observed by means of the spectroscope, its radiation is dispersed into a band of general darkening longitudinally crossing the lines of the photosphetic spectrum. This band varies in intensity in different spots, being in large spots generally very black, and in small spots of a decidely lighter tint, the difference being due, no doubt, to the varying quantity and depth of the materials contained in the spots. If the materials in a sun-spot were simply opaque to light, this variation in tint might be accounted for by the sparseness or denseness with which the particles were packed together. The effect produced, however, seems not at least wholly to be due to the stoppage of light by opaque particles, because with highly dispersive spectroscopes the dark bank is seen to be discontinuous, crossed by bright spaces. With very powerful instruments the band of general darkening has been resolved into a series of fine lines, and bands, or congeries of lines, indicating a gaseous constitution.

Besides this almost continuous band of general darkening, the Fraunhofer lines are variously affected in a sun-spot. The most general characteristic is, that, where they cross the spot, they gradually widen through the penumbra to the umbra, in which part of a spot the widening effect is most pronounced, and then gradually narrow so as to present a sort of spindle shape. Not all the Fraunhofer, or dark, lines of the solar spectrum are



Life-history of the large sun-pot group, February 4 to March 14, 1917 Stonyhurst College Observatory

* *Science Progress.*

so affected when they cross a spot, but only some. Taking the lines due to any given metallic vapor, iron for instance, some lines will be widened in this manner and some not. Some, too, will be weakened where they cross a spot. And speaking of metallic lines in general, some will be obliterated in a spot, some will be thinned as, for instance, the lines of hydrogen; some will be reversed, if indeed it is true reversal of the line, and not rather a doubling of a line, which is single in the photosphere. Other lines, though weakened in intensity, will be widened; other lines will extend as widened far beyond the limits of the spot; while others will have a sort of fuzzy fringe attached to them, and be confined as spot bands to the umbra.

In addition to these variations in the line spectrum of a spot, there is a whole series of bands made up of a great number of lines forming flutings. These bands may become so prominent in a big spot, as, even with a large dispersion, to present the appearance of a local strengthening of the general darkening, or quasi-continuous band, at the background of the line and fluted spot spectrum. The appearances presented by this complicated spectrum would seem to be for the most part due to the absorption of a mass of metallic vapors and gases of great density, the varying density or thickness of the strata being denoted by the variations in the general darkening of the background of the spot spectrum.

The lines that are most widened in the sun-spot spectrum are due to vanadium, titanium, and silicon, and it is generally the fainter lines of their normal photospheric spectrum that are the most affected by widening, an indication of the low level of a sun-spot. Next in order of widening, at least in the region of the red and yellow parts of the spectrum, which has been the portion especially studied at Stonyhurst, come calcium, sodium, nickel, manganese, iron, while cobalt, scandium, and chromium are represented by well-marked lines. It is noteworthy that most of the elements enumerated form the first half of the first long period in the chemical periodic system. This would seem to indicate that the level of sun-spots is that of the metals with atomic weight about 50, for it is conceivable that, as we advance outwards from the solar photosphere through a mixture of metalic vapors and gases, there should be a layer or stratum in which vapors of the metals connected by any one period of the periodic law should be most abundant.

Titanium also appears as titanium oxide in the banded spectrum of sun-spots, in which, too, are represented magnesium hydride and calcium hydride, with possibly a much more familiar compound in the form of superheated steam. A banded spectrum of chemical compounds is generally indicative of a lowering of temperature. Hence it is argued that sun-spots are at a lower temperature than that of the photosphere. To the contrary, however, it is urged that a banded spectrum may be produced by pressure alone, and, moreover, some compounds, though titanium oxide is probably not among them, are formed with an absorption and not with an evolution of heat. If, however, appeal be made to the laboratories of the stars, titanium oxide in particular, as Prof. Fowler has shown, is responsible for a whole series of characteristic bands in the spectra of stars of Type III., such as a Herculis. It is generally supposed that Type III., or red stars, are at a lower temperature than the yellow stars of Type II., which give a spectrum like that of the sun's photosphere. Moreover, in the variable star Mira Ceti, which belongs to Type III., the titanium oxide bands are much weakened at brighter maxima of the star's light; and the photosphere of the star is probably hotter at such maxima, as the hydrogen bright-line spectrum shows the blue radiation Hβ, which is not seen when the titanium oxide bands are more prominent.

Again it is generally supposed, though it has not been proved, that the electric spark represents a higher temperature than that of the arc, and especially of the flame of the arc. The lines that are widened in sun-spots are those which appear in the arc flame, while those weakened are the so-called enhanced lines which appear in the electric spark spectrum of an element. But the argument is inconclusive, as some experiments of Dr. Hemsalech show the enhanced lines in a flame at a lower temperature than the flame which gives the arc lines It may be doubted whether these differences of behavior in the lines of an element in arc and spark are due at all to temperature, but rather to a difference in the condition of electrical excitation. Even in experiments with the electric furnace, the heating is produced by electrical means, and the resulting spectra of the metals heated in the graphite chamber may be conditioned, as in the arc itself, by the mode of the production of the heat. On the whole, however, opinion at present tends to the view that the vapors in sun-spots are at a reduced temperature being at a temperature of about 3,500 degrees on the absolute Centigrade scale, while that of the photosphere is at a temperature of 6,000 degrees on the same scale Hence sun-spots, though intensely bright in themselves appear to be dark, as the cooler vapors constituting them absorb the more intense radiations of the sun's photosphere.

The spectra of sun-spots, as observed at Stonyhurst for more than thirty years, are substantially always the same, the same lines being always picked out for widening or weakening, or obliteration, and for the other effects to which lines are subjected in the spot spectra, and also to the same degree, except, perhaps, that the intenser iron lines are more apparent in the minimum than in the maximum period of sun-spots.

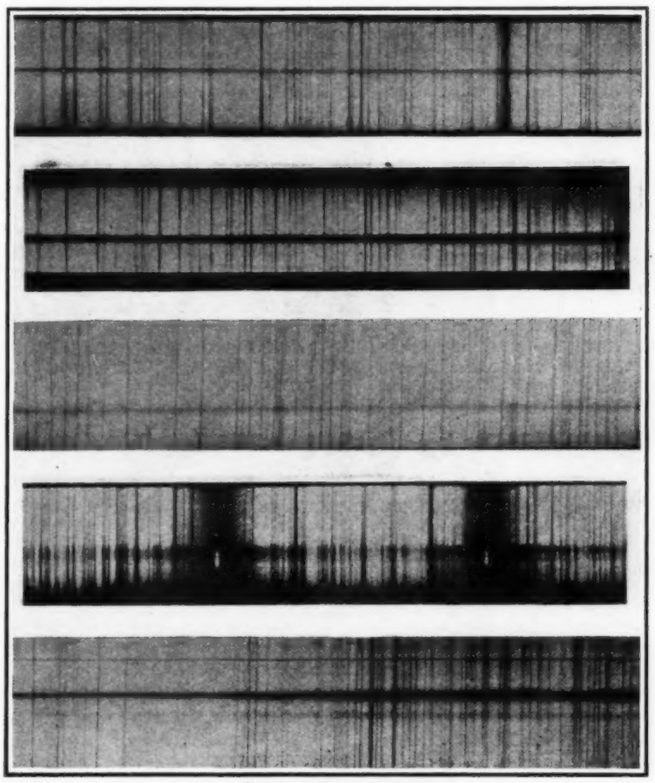
The discovery of the magnetic field in sun-spots, made by Prof. Hale with the magnificent and highly dispersive apparatus at Mount Wilson, is one of the most brilliant and important made in recent years. In the year 1896 Prof. Zeeman had demonstrated a new relation between light and magnetism, by proving that the emission and absorption of the luminous radiations are modified, when exposed to the influence of magnetic forces. He experimented with a flame containing sodium vapor, which was placed between the poles of a strong electromagnet. The effect produced was that when the current was passed through the coils of the magnet, the D lines of sodium, a double yellow line in a spectroscope of sufficiently high dispersive power, were seen to be widened. Subsequent experiments showed that nearly every radiation observed in a powerful spectroscope is split into three components when the original radiations are observed in a direction at right angles to the lines of force. When, however, the lines are observed along the lines of force, the central line of the triplet disappears, and the two terminal lines remain which are found to be circularly polarized in opposite directions. With suitable polarizing apparatus one or other of the two components of the double can be quenched, leaving the other unchanged. Now, in sun-spots the spectrum when observed by means of a spectroscope of moderate dispersive power, as compared to modern instruments, appears to be full of broadened and thickened lines. More than a quarter of a century ago at Stonyhurst some lines appeared to be doubled in the spectrum of a sun-spot, suggesting at the time rather the appearance of a bright reversal in the widened dark line, than of two separate lines. But Prof. Hale, armed with the powerful instruments of Mount Wilson, argued that if a sun-spot is an electric vortex, and the observer looks along the axis of the whirling vapor, which coincides with the direction of the lines of force, he should find the spectrum lines double, and by means of a polarizing attachment of a Fresnel rhomb and Nicol prism to a spectroscope, he should be able to quench either component at will. This test he applied triumphantly on Mount Wilson to two spots in June, 1908, and at once found all the characteristic features of the Zeeman effect. Most of the lines of the sun-spot spectrum are widened in the magnetic field, but others are split into two components.

When a current of electricity flows through a coil of wire in the form of a helix, lines of magnetic force are produced threading the helix. Putting the first finger of the right hand on the coil in the direction of the flowing current, the extended thumb points to the north pole of the magnetic lines of force. It would seem, then, that a sun-spot, and the vapors constituting it, is essentially a vortex, or tornado, or whirl of electrons or electric particles, which give rive to the magnetic field of force. In the case of a current flowing in a helical wire a reversal in the direction of the current would cause a reversal in polarity. In a laboratory, when a polariscope is so adjusted as to transmit one component of a line doubled by a magnetic field, when observed along the direction of the lines of force, this disappears and is replaced by the other component when the current is reversed. This test also Prof. Hale applied to sun-spots, and found that in typical sun-spot groups of leader and follower spots, the two spots had opposite polarity. The intensity of the magnetic field in sun-spots is sometimes as high as 4,500 units, or about 9,000 times the intensity of the earth's magnetic field. This magnetic field in sun-spots diminishes very rapidly in passing upwards from the sun's surface, and it is probable that the vortex producing the field is at a comparatively low level.

Prof. Hale's discovery was suggested by the whirls observed on the Hα line in spectro-heliographic photographs of the flocculi in the environs of sun-spots. The different behavior of the spectrum lines in a spot when observed in a polariscopic spectroscope, when near the limb, and when approaching the sun's central meridian, is also a crucial test of the truth of the theory. In the one case the line of sight is directed at right angles, and in the other, along the lines of force. It demands, however, a gyratory motion in the vapors in the environments of sun-spots.

Yet it is doubtful whether the umbra and penumbra of the spots themselves partake in this gyratory motion. For Mr. Evershed finds that if a sun-spot be observed with the spectroscope slit placed across it diagonally from the sun's center, and when the spot is between 30 degrees and 50 degrees from the central meridian, the lines of the spot spectrum are displaced in the penumbra in opposite directions. If the spot is east of the central meridian, the displacements indicate a motion of approach on the side of the spot nearer the sun's center, and a motion of recession on the side of the spot nearer the sun's limb, the reverse being the case when the spot is west of the central meridian. Moreover, the displacements observed when the spectroscope slit bisects a spot in a direction at right angles to a line joining the spot and the center of the sun's disk are small. If the displacements were due to rotation in the spot, this latter position of the slit should show them to the greatest advantage. The only explanation to account for these displacements in the spectrum lines over the spot is that they are caused by radial movements in the vapors constituting the spot from the center outwards towards the penumbra. This would accord with the radial structure of the filaments in the penumbra of spots as observed visually.

These interesting observations of Mr. Evershed have been extended and amplified by Dr. St. John at the Mount Wilson Solar Observatory. He observed the radial velocities in sunspots in the cases of 506 lines of the spot-spectrum, representing 27 chemical elements, and lying at levels extending from the lowest that can



Spectra of sun-spots

1.—Region of the D lines. 2.—Reversals in the H and K lines. 3.—Region λ5455-5680. 4.—Region λ5300-5460 5.—Radial velocities in sun-spot, F region. (Evershed.)

be observed to the highest regions in the chromosphere. The reversing layer is the name given to a shallow stratum of vapors and gases some 500 miles in depth, which overlies the photosphere or brilliant light-giving surface of the sun. It is in this region that the absorption which gives rise to the dark lines in the solar spectrum takes place. When the moon covers the sun in a total eclipse, the reversing layer at the edge of the sun is isolated, and immediately, for a few seconds only, all the dark lines of the solar pectrum become bright, the so-called "flash spectrum" being produced. Above the reversing layer lies the chromosphere, or atmosphere of hydrogen, some 3,600 miles in depth, according to the observations made at Stonyhurst during twelve successive years. From the atmosphere rise the flames of hydrogen and calcium and helium, sometimes to enormous heights, called the prominences. From eclipse observations, the mean height to which hydrogen rises is about 4,500 miles, helium 3,500 miles, and calcium about 6,000 miles. The levels of hydrogen and calcium flocculi are presumably still higher, possibly between 15,000 and 16,000 miles. These different vapors and gases are not arranged in successive and isolated layers, like the coats of an onion, but they interpenetrate one another, and rise from the photosphere to different heights. Faint thin lines in the solar spectrum would indicate a rise to a much lower level than would thick black lines. Now, in the spectrum of a sun-spot it is mainly the faint lines that are affected by widening, indicating that a sun-spot does not rise very high above the photosphere, if we regard the umbra as an elevation, and the penumbra as a shallow depression.

Again, a vapor of a metal, for instance that of iron, will be represented by lines of various intensities in the solar spectrum, ranging from very faint lines to some of the most prominent. Hence it follows that some molecules giving certain radiations of iron, as a typical vapor, are confined to low levels, while others extend to higher levels. Now, Dr. St. John finds, and his results have been corroborated by still more recent observations of Mr. Evershed, that the radial velocities of the vapors in the penumbræ of sun-spots decrease with an increase in the intensities of the spectral lines. In other words, low-lying vapors move outwards more rapidly than higher-lying vapors. For instance, in the case of iron there is a gradual decrease in velocity from 1.05 miles per second for lines of intensity 1, to 0.35 miles per second for lines of intensity 8. Taking in the whole series of lines of iron, from intensity 00, or very faint lines, to very strong lines of intensity 40, and referring the other elements to the same scale, a sort of sounding-rod is constructed to gage the depths of sun-spots. One interesting result is that we see to a greater depth into the sun in the red end of the spectrum than in the violet.

Again, after a certain level in a sun-spot has been reached, at a depth represented by iron lines of intensity 10, that is from eclipse results about 2,000 to 2,500 miles above the photosphere, the gases and vapors, chiefly sodium, calcium and hydrogen, flow inwards. This means that there is in the upper levels a sort of indraught. Hence we may conclude, from the evidence, "that the outward velocities in the reversing layer at the outer boundaries of the penumbra of sun-spots may be referred, with great probability, to a low-lying vortex." The quotation is from the Annual Report of the Director of the Mount Wilson Solar Observatory (Carnegie Institution of Washington) for the year 1913. But we must confess that we fail to see any evidence for a whirling or vortex-motion in the observations summarized above, so far as they concern the radial movements in sun-spots. Undoubtedly there is evidence of a whirling or vortex motion in the flocculi above sun-spots, that is in the hydrogen flocculi.

Among Evershed's conclusions from his observations (*Kodaikanal Observatory Bulletin*, No. 51, 1915) he states that detached penumbræ without nuclei or umbræ show no radial motion; that the radial motion may be continued for a considerable distance outside the limits of the penumbra, or it may stop short at these limits, that there is usually an acceleration of velocity from the umbra to the outer limits of the penumbra, and then a sudden fall to zero in most cases: and that there is a tendency to diffusion of the lines in the direction of displacement near the outer limits of the penumbræ in some spots, indicating turbulent motion. A terrestrial analogue to the radiation movement and diffusion in sun-spots would be the welling-up of substances from the crater-cone of a volcano, and their lateral sperading in all directions outwards.

In Mr. Evershed's latest paper on the radial motion in sun-spots (*loc. cit*) he details some movements at right angles to the radial movement. These movements might be interpreted in various ways, but one possible interpretation is that they indicate a general descent of the gases over a spot. Again, in photographs taken at Stonyhurst of the calcium radiations (H and K) over sun-spots, more frequently the bright calcium lines are single near the center of the umbra, but become doubled with an ever-widening absorption between them as they recede from the center. An obvious interpretation of this appearance is that the absorption is due to the greater quantities of cooler vapors, as welling up from the spot center they fall to lower levels.

Taking into account, therefore, the Wilson effect undoubtedly present in the penumbra of round regular spots, when near the sun's limbs, and the appearance of the umbra as overhanging the penumbra when very near the limb, as also the spectroscopic evidence, set forth above, we might picture a sun-spot somewhat as follows. The umbra is a mass of cooled, absorbing vapors, which, mountain-like, rises above the level of the photosphere into the reversing layer. Flowing from it and sinking, these absorbing vapors seek a level slightly below that of the photosphere, and pass into it as dark radial streams giving the appearance of the penumbra. The penumbra itself is in round spots in the form of a shallow saucer-like cavity, the lowest portion being due to the falling-in of the photospheric clouds, caused by the upush of the mass of vapors constituting the umbra. This falling-in and heaping together of the photospheric clouds to fill the partial void formed by the ejection of the umbral vapors account for the bright ring which is generally seen separating the umbra from the penumbra. Around the sun-spot thus formed, but in an upper level far above the reversing layer, circulate the hydrogen flocculi, giving rise to the appearance of the solar vortices, in which are generated by the friction of the various gyrating vapors and gases electric currents with the accompanying magnetic fields.

Scent-Producing Organ of the Honey-Bee

It is reported that Nassonoff first described the morphology of the scent-producing organ of the honey-bee. His original work in Russian can not be had here, but according to Zoubareff (1883), Nassonoff did not describe the structure of this organ as seen by the present writer (1914), and he suggested that the gland cells of the organ produce perspiration. Sladen (1902) called this organ a "scent-producing" organ, but did nothing more than to describe the articular membrane between the fifth and sixth abdominal terga (propodeum not counted) of worker bees.

Externally this organ appears as a white transverse stripe near the distal end of the abdomen, but is visible externally only in worker bees that are fanning, however, it is present in all workers and queens, but has never been found in drones. The white stripe is the articular membrane and it is so folded that it forms a pouch which encircles about one-half of the abdomen and terminates on either side of the abdomen just above the articulation of the tergum and sternum. Just beneath the pouch lie many unicellular glands, each of which is connected with the bottom of the pouch by means of a chitinous tube through which the secretion passes into the pouch. The gland cells are modified hypodermal cells; they are granular and have conspicuous nuclei which contain many globular, refractive bodies. Each chitinous tube arises in the cell at the center of a clear area, the ampulla, which contains many radial streaks.

Judging from the morphology, we may reasonably conclude that the gland cells secrete a substance throughout their cytoplasm. This substance collects in the ampulla which serves as a reservoir, and from the ampulla the secretion passes through the chitinous tube to the exterior where it runs into the pouch. That the gland cells secrete an odorous substance is shown by the fact that when the articular membranes forming the pouches are excised, they appear wet and give off the characteristic bee odor, while the other articular membranes neither appear wet nor emit an odor. This view is further supported by the following: A virgin queen, emitting a very sweet and pleasant odor, was severed between the thorax and abdomen; when tested the thorax did not emit the sweet odor, while the abdomen did. The abdomen was then split into dorsal and ventral halves, and when tested only the dorsal half gave off the sweet odor. The dorsal half was next severed between the fourth and fifth terga, and in this case the portion containing the last two terga emitted a sweeter odor than did the other portion.

The groovelike indentations in the chitin forming the pouch may serve two purposes: (1) To give more flexibility to the chitin, and (2) to retain the volatile secretion and to help prevent a too rapid evaporation of it. So long as the abdomen is straight, the pouch is well protected and the liquid can not evaporate rapidly, but when the abdomen is considerably bent, the entire pouch is more or less exposed to the outside air.

The gland cells in old workers and queens are highly developed and are proportionately the same size, but the size of them increases little after the bees have emerged, and not until a few days later do they function in full capacity, judging from the fact that the odor emitted by workers just emerged gradually becomes more pronounced up to the fifth or sixth day.

The present writer failed to find gland cells connected with the articular membranes in the abdomens of drones, but they were not looked for elsewhere, and it is possible that some kind of a scent-producing organ may yet be found in drones. This assumption seems reasonable for sometimes when the abdomens of young drones are slightly squeezed, a very thin and whitish liquid may be seen on the abdominal articular membranes. At other times a clear liquid may be observed on the articular membranes between the fourth and fifth, and fifth and sixth abdominal terga; and it has already been stated that drones emit a faint sweetish odor.—Abstract from Smithsonian Miscellaneous Collections, Vol. 68. No. 2. "Recognition Among Insects" by N. E. McIndoo, Ph. D.

The Storing of Coal

A series of experiments, started in 1910, to determine the effects of storage upon the properties of bituminous coal has recently been completed by the Engineering Experiment Station of the University of Illinois. The object has been to devise methods of storing which will avoid the risk of spontaneous combustion and to determine the extent to which coal deteriorates in storage.

Professor S. W. Parr, under whose direction the tests have been conducted, summarizes the results in *Bulletin* No. 97 of the Engineering Experiment Station. It is shown that, if properly sized and carefully handled, coal may be stored without danger of spontaneous combustion; that the actual loss of heat value, or deterioration, resulting from storage is slight; and that underwater storage eliminates entirely all risk of spontaneous combustion or of deterioration. The extent of the waste and economic loss incident to the present method of seasonal production, with its attendant abnormal demands upon transportation facilities is discussed, and it is estimated that the lack of storage facilities in large distributing centers necessitates a capital investment in mines and railroad cars of $500,000,000 in excess of the amount which would be required if production could be maintained at a uniform rate throughout the year.

Synthetic Rubber

The manufacture of acetone with a view to the production of synthetic rubber is of considerable importance in Germany at present. The importance of this new industry is indicated by the fact that some of the largest firms in Germany have been occupied with this problem for some years. There are firms in Germany producing 10 to 50 tons of carbide per day in order to convert the acetylene into acetic acid and acetone, the latter being intended chiefly for the production of synthetic rubber. This new industry should be of special interest to Switzerland, according to a communication from the Swiss Acetylene Association, since the necessary carbide will in the future be available in large quantities in that country. After the war the export of carbide will be considerably reduced, and this product will therefore become much cheaper. On the other hand, the price of rubber will remain high for several years.

Preserving Potatoes by Lime

The French Department of Agriculture lately issued the following indications as to the best method of preserving potatoes against rotting, such as is likely to occur in damp places. By employing the proper method, it is possible to diminish the dampness within the piles where the air does not enter or only circulates very slowly. To avoid this, a substance which absorbs water and having no action upon the potato must be employed, and for this purpose it is found that lime is the best substance, as it costs least, is easy to handle, and is best known. In practice the method can be applied in the following way. It is to be remarked that when potatoes are stored up after being well cleaned beforehand, they commence to exude moisture, and must be gone over again. The storage place is sprinkled with quick lime, and each layer of three or four inches of well-dried potatoes is sprinkled over with lime; the same on the outside of the pile. When sorting as above stated, the imperfect ones need not be thrown away, but the bad parts cut out and the rest fed to stock after cooking or passing through a dryer or baking in a furnace; or they can be sent to a starch factory if one is near by. As to the amount of lime to be used, the proper quantity is about ten pounds of lime for 1,000 pounds of potatoes.

Whale Beef and Whales

By Edward T. Martin

I HAVE eaten almost everything that flies, walks or crawls, from crows to rattlesnakes and some that do neither, as abalones that grab hold of rocks and stay in the same place during their natural lives unless pried loose, and my only comment is that some things are just as good as others if one doesn't know what he is eating. For instance, young sparrow hawks make a better pot pie than old pigeons and fried rattlesnake with cream gravy is more tender and juicy than spring chicken a la Maryland. It is the knowing that turns one's stomach; but in the days when my imagination ran the wildest, and that is going some, the idea of ever eating the flesh of the leviathan of the deep, in other words whale meat, never entered my head. It has come though and I have joined with the crowd in another attempt to shoot a torpedo into the ribs of the high cost of living. Let me tell you also that from an epicurean standpoint, whale meat isn't so awful bad. It is better than crow, not so tough as alligator, nor so rank as buzzard, all of which as an investigating young man it was my good fortune to sample, largely so as to be able to say, "Oh! yes, crow. It isn't half bad when you learn to like it." Or buzzard? "Yes, stew it with red pepper and lots of garlic and you can never tell but the tail, the buzzard end, has been left off and except for the color of the meat that it is real turkey." This is particularly true if the pepper is of the Mexican variety—real hot. Nor are fish, ducks or even blue bills to be compared with whale steak.

In the raw, whale beef is a dead ringer for venison. Not so many days ago a friend left a liberal section of boneless deer meat at my front door saying, "Killed this buck yesterday and thought you might like enough for dinner so I brought some over."

It so happened that the managing partner of my household was out skirmishing around the various down town markets and among other things investigating the whale meat situation. On her return the venison as it lay on the kitchen table, was shown her with the remark: "See I went down to the City Market and got a pot roast of whale beef for dinner."

She turned it over, sniffed and said, "Well, you got a bad cut, that's all I've got to say," but it wasn't for she kept right on. "Why didn't you tell me you were going to buy meat? Now we've got whale beef to last a week and the weather is warm too."

Side by side as the pieces of meat lay, one not in the know would be unable to tell which was which and it took much explaining to make the lady of the house believe that mine was really and truly venison, at least until the eating time came, then there were no more complaints.

The University of California, the Fisheries Bureau and several other institutions of wise heads are out in printed circulars attesting to the value of whale beef for food and recommending its use but its own cheapness 12½ cents a pound, is the best drawing card. There is no bone, no waste, all good meat.

I have no figures to show just how much "beef" there is in a whale's carcass; a good deal depends on the size and the breeding of the beast. From several tons up I should imagine. A small whale is three times as long as an ox, and some ten times that long.

For a number of years coal oil and its products forced whales, their oils and flesh into a condition of innocuous desuetude, at the same time steel supplanting whale bone in all articles of feminine apparel, as few whaling ships braved the storms of the arctics on what even a child could see would prove a losing venture. Several of the shore stations closed down, the one or two that ran made no money and the great mammals had a season of quiet which it is to be hoped they enjoyed for in 1914 things in the oil and bone line began to improve. Some of the old hulks slowly rotting their lives away on the mud flats, were repaired and sent to the Alaska whaling grounds. Shore stations were refitted and a small boom was on. Then came the excitement about whale beef which still further helped things and now even the peacefully inclined mammals of the frozen North are sufferers from cruel war.

There must be a lot of sport fishing for these monsters with line and reel which is what it virtually amounts to. A 3¼-inch muzzle loading gun is mounted on the forward deck of each whaling steamer. It first is loaded with a bag of black powder, then a harpoon bomb with expanding arms is placed on top of the powder bag, the bomb and harpoon end projecting beyond the muzzle. The effective range of this affair is about forty yards. A considerable length of strong line is attached to the harpoon head, coiled on the deck where it can run out freely and the other end carried to a steam winch a little distance to one side and back of the gun. The vessel is carefully worked up on a whale, the trigger of the gun pulled, the harpoon strikes the leviathan about midships, the bomb explodes, damaging the interior organization of the whale much as a four-inch shell would a submarine, the arms open up and the whale is fast.

The big fellow possesses much vitality and either sinks and sulks or is off and away. Then the winch man has his hands full. The winch is in fact nothing but a giant reel and the whale must be played even as all of us have done with a bass or trout. The Captain shouts, "Wind in, wind in. Don't let him get any slack on you," then as the giant mammal dashes for the open ocean in hopes of liberty, "Play him, play him, I say. Ease up on the line. There is too much strain on it."

Amateur fishermen tell of the work and excitement in landing a four or five pound trout. Imagine the thrills with a 10,000 pound beauty fast on the line, one that if he only had the sense could wreck the vessel and destroy his tormentors.

In the end it is the old story over again, man wins. Each run of the whale is shorter than the one before. He tires, is drawn longside and once dead, a line is looped around his tail which with the harpoon rope holds him close to the vessel, while an active sailor with calks on his shoes jumps on the monster's slippery back and by aid of an air pump, forces air under his skin much as if pumping up the tire of an auto, this because the tendency of a whale when dead is to sink, but if full of air will float indefinitely.

Should other whales be in sight as is often the case the dead one is flagged, that is, an iron shod staff with a signal flag at the top is driven into its back, lines are cast off and the whaler steams away in search of another victim.

The record for late years is eleven sperm whales taken one July day by three killing steamers, the property of the United States Whaling Company, working together.

If no other whale is sighted, a tow line is made fast to the one already secured and it is taken to the station, hauled up on an inclined platform by aid of a winch and the blubber having first been creased with sharp cutters, is torn off in strips, also by aid of steam, and carried by a chain conveyor to large open topped boilers where steam is turned on and the fat cooked for about eight hours, which done the oil is drawn off and the cooking process repeated. Sometimes a third cooking is necessary for the extraction of all the oil. The remainder of the carcass was, before the days of whale beef, cut into 40-pound chunks and boiled in tight kettles under 65 pounds pressure, the oil drawn off—it is poor in quality—the cooked meat put through a drier, cooled, pulverized, sacked in 200-pound sacks and sold as a fertilizer, but now when the cry is "conserve everything," it will be canned whale beef, corned whale beef, smoked whale beef and whale beef put up in every way the ingenuity of the packers can suggest.

The oil which before the war was slow of sale, around 25 and 30 cents a gallon, in the general demand for oils and fats, has advanced in price until at present it is a question of "write your own ticket" for those fortunate enough to have any for sale. They can name their own price and with a little waiting, the buyers will come.

The by-products, fertilizer and bone meal, also have made a very considerable advance from the former price of $25 a ton but not proportionate to that of oil.

The present year many experiments have been made to utilize all the fish refuse, the heads, the entrails, the bellies, the tails, formerly thrown away. Just how successful these efforts have been it is hard to say for the year is not over, it is a long distance to Alaska and the fishing fleet is just beginning to return, so who knows?

I am informed that the shore station at Gray's Harbor bids fair to have a prosperous season.

In 1914 the cash received for the whales taken by the shore stations averaged a trifle over $600 a whale, there being no bow-heads taken then and no whale bone saved, which accounts for the money value being so much less per whale than those taken by the far off shore fleet. Now, however, with all sea products booming and a demand for whale beef growing so fast that it must soon take all the choice cuts the whale fisheries companies can offer and at a liberal price, it naturally looks like the catching of whales for the next few years would be a profitable game to play, with no limit beyond the supply of the marine-mammals themselves, for slow breeders as they are in common with all long lived animals, it will not be very many years before another species of today will have followed into oblivion the buffalo, the passenger pigeon, the moa, the mammoth and the species of birds and animals that lived in the long ago.

That whale beef has obtained a good start in the race for popular favor is shown by the fact that twice this week "All sold out" is what the man behind the counter told his would-be customers at whale headquarters in Oakland and the housewife is learning if she wishes a juicy steak of the sea food for dinner, she must go early, wait patiently in line until her turn comes and not kick if two bits' worth is all the man will sell her.—*Hunter, Trader, Trapper.*

New Feeding Stuffs Used in Germany During the War

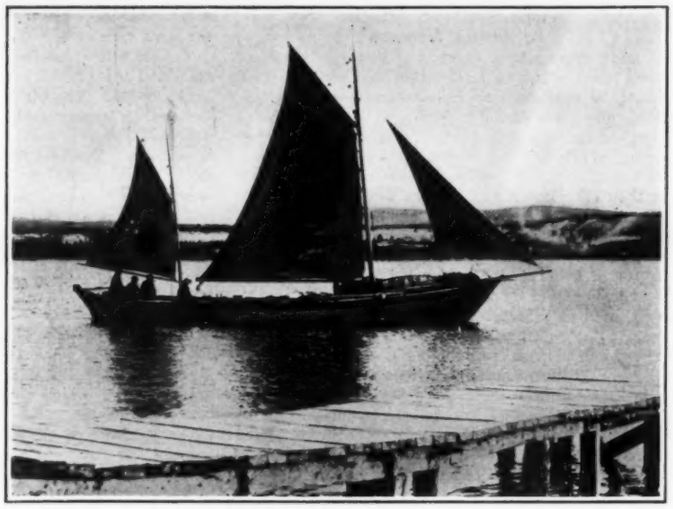
(1) *Rhubarb leaves.* The green leaves contain 90 per cent of moisture, 2.78 per cent of protein, and 0.4 per cent of fat. The dried leaves are said to be better than hay of the first quality. (2) *Seaweed.* As a rule seaweed contains little protein and fat, but a large quantity of nitrogen-free extract and crude fiber. When used as a feeding stuff, no trace of its smell could be found in the meat or in the eggs. It is advisable to give the seaweed in the ground, dry state, as a supplementary food. (3) *Straw meal.* The ground straw of cereals is unsatisfactory for pigs, cattle, and horses. (4) *Spelt chaff meal* is not superior to whole chaff. (5) *Concentrated straw fodder.* By boiling straw in an alkaline solution under pressure, a concentrated, easily digested food is obtained. It is mixed with about 30 per cent of molasses and the whole dried. The product contains 3.55 per cent of protein (amides), 29 per cent of nitrogen-free extract, and 53 per cent of fiber. To supply the deficiency in albumin, the fodder was enriched by the addition of dried yeast, now replaced by ground lupin seeds freed from their bitter elements. Thus enriched, it contains 6-10 per cent of protein, 44-45 per cent of nitrogen-free extract, and 28-34 per cent of fiber. Feeding experiments showed this product to be suitable for all animals, and capable of replacing oats for horses. (6) *Crushed and ground maize ears.* The feeding value does not exceed that of wheat chaff, and it is not recommended. (7) *Heather stalks.* An excellent food may be prepared from the leaves, flowers, seeds, and fine stalks of heather. It contains about 4 per cent of protein, 3 per cent of fat, 45 per cent of nitrogen-free extract, and 35 per cent of fiber. (8) *Kohl-rabi by-products.* The decomposing roots, made into slices and then dried, gave a fairly good food. Another food prepared from the peelings contained so much sand that it could not be used with safety. (9) *Ground sugar-beet seeds.* Seeds which have lost their germinating power are ground. They contain about 11 per cent of protein, 4 per cent of fat, and 9 per cent of mineral matter. Their nutritive value is two-thirds that of wheat bran. (10) *Parsley seed.* Seed which had remained unsold was crushed. It contains about 23 per cent of crude fat, and can be given in moderate amount to animals receiving rations poor in stimulants. (11) *Wild radish husks.* Nutritive value 40 per cent that of good barley. Not suitable for pigs. (12) *Mixture of brewers' grains and yeast.* By a special process the dry grains are mixed with the moist yeast, and the whole dried. The mixture contains about 75 per cent of grain and 25 per cent of yeast, and is most suited for horses and cattle. (13) *Wine yeast.* The fresh yeast is washed to free it from tarter and made into a cake. (14) *Ground grape pips.* The pips are obtained from grape residues after distillation to remove alcohol. They are ground, and form a food very rich in crude fiber, with a nutritive value corresponding to that of medium quality meadow hay. (15) *Beechnut cake.* The ground nuts contain about 18 per cent of protein, 4 per cent of fat, 28 per cent of nitrogen-free extract, 19 per cent of fibre, and 11 per cent of mineral matter including 6.5 per cent of sodium chloride. The last was added to disguise the taste of tannin, in which the nuts are very rich. (16) *Walnut cake.* The nuts are pressed with the shells and give a cake very similar to beechnut cake. The cake is also prepared from nuts pressed without their shells, and then forms a food readily eaten by cattle. (17) *Foods for fattening pigs.* Six varieties are described, only two of which are considered satisfactory: one, made from crushed maize, ground maize ears, and acorn meal, contained about 9 per cent of protein and 3 per cent of fat; the other was composed of corn bran, crushed corn, barley, oats, acorn meal, ground seeds of weeds, seaweed meal, and fish meal, and contained 15 per cent of protein. (18) *Poultry food.* Many by-products of little value are being sold. (19) *Horse food.* One is made from corn chaff, dried beetroot, and epa meal. (20) *Feeding meal.* One contained ground spelt chaff, ground grape residue, straw meal, and 2.5 per cent of sodium chloride.—Note in the *Journal Society of Chemical Industry* on an article by M. KLING, in Landwirtsch. Jahrb. f. Bayern.

Decolorizing of Anti-Halo Plates

ANTI-HALO photographic plates can be decolorized in their under layer by the use of a moderately concentrated solution of sodium bisulphite, poured into a dish which has the bottom covered by a zinc plate, of course, well cleaned and brightened. The reaction of the bisulphite upon the zinc produces hydrosulphite of sodium, and this salt is the active principle of the substance known as "leucogen" which is sold for bleaching anti-halo plates. Commercial bisulphite solution is diluted with three or four times its volume of water, and when at the proper strength, it attacks the zinc, giving off sulphurous gas whose odor shows that the action is going on properly.

Photos by Gilliams Service

Indians arriving at a trading post with furs



A fur trader's boat on Hudson Bay

The Fur Trade of the United States

America Now the Chief Trading Center of the World

Or the many commercial changes due to the war not the least interesting is the way the United States has gained from the old world the premier position as a fur-selling country. Today of greater importance than the English or Russian fur auctions are those now held regularly in New York and St. Louis and they are attended by buyers from all over the world. High prices have so far obtained. Never before has there been such a tremendous demand for furs as at present and strangely enough the most popular fur this season of war time economies is the most expensive of all—Russian sable.

America has become the chief fur trading center of the world.

Recently there were held in New York and St. Louis great auction sales of furs at which millions of dollars worth, in the raw state, were sold to buyers who were attracted to the auction from all parts of the world. About the only foreign buyers of importance who were missing were representatives of Germany.

It is now proposed to hold these sales three times a year and there is every indication at present that after the war these auctions will not only be continued but even increase in importance.

This shifting of the fur center from Europe to America is by no means the least interesting or important of the many commercial changes of the world's markets due to the war.

All things considered, the United States is only coming into her own in becoming the leading fur market, as ever since the white man first came here, America has ranked among the world's largest fur-producing countries, but until the present war gave Europe something more serious to think about we played second fiddle in the selling end of the business.

Of course, auction sales of furs are still being held in London, the before-the-war fur center, but neither in attendance, size nor quality of the offerings do they resemble the sales of the days of peace. American buyers no longer play the parts they formerly did in England. The submarine is one of the chief reasons. It has caused a scarcity of ocean freight space and a big jump in war risk insurance on cargoes. Then the war and the revolution have played havoc with Russia, a big feeder of the London market, both as a seller of furs and as a producer. The great fair at Nijni-Novgorod, that ancient Russian town which for years has been a Mecca of fur buyers from all over the world, was held this year, as usual, but the attendance, was almost entirely made up of Russian buyers. A few French and English purchasers were on hand but Americans were conspicuous chiefly by their absence. Other Continental fur centers, such as Leipsic and Frankfort, have been obliged to either abandon their activities altogether or to carry them on such a small scale that they attracted little, if any, attention, except locally.

While the great bulk of the buying at the American fur sales has been for civilian purposes, the purchases ranging all the way from Russian sables at dazzling sums to the skins of ordinary house cats at trivial prices, not a little of it is done by the nations at war. At the recent sale in New York, for instance, the heaviest buyers of bearskins were Englishmen. It was reliably reported at the time that the pelts were to be made into hats for wear by certain branches of the British army. With our own Government in the market for fur or fur-lined garments, especially for use by the Aviation Section, there was considerable indirect buying for Federal account. Uncle Sam now also participates in the fur auction business as a seller.

For a long time previous to the beginning of hostilities sealskins had to be sent to Europe for finishing, later to be returned to this country and re-entered in the dressed state at a customs tax of 20 per cent. advalorem. The necessity for taking this trouble in getting the skins

Fur hunting in the winter woods

put into condition for cutting up into garments naturally had a detrimental effect on the prices they brought in the raw state. Now, however, the finishing can be done in this country and the Government in consequence has become a seller of sealskins at the New York and St. Louis auctions.

The cutting down of the supplies of skins received from other countries is another way in which the war has thrown Uncle Sam on his own resources in reference to furs. This difficulty has been offset to an extent by the reduced shipments of skins from the United States. However, as a result of depleted supplies of foreign furs, prices have advanced sharply, particularly on skins of animals not native of this country. The law of supply and demand has had a hand in the increases, but it has been ably aided by fashion which is this winter figuratively crying for furs and still more furs. Proof that the women of the country are responding to the cry is seen in the fact that, despite the high war prices, the American fur trade as a whole is enjoying one of the best seasons it has ever had. A factor in this prosperity is the increased skill of American manufacturers and fashion artists. So marked has been this increase that it may truly be said now that New York rivals Paris in the designing of rich fur garments.

Strangely enough, among the most popular furs this season of war time economies in nearly every direction is the most expensive of all, Russian sable, the "royal fur." In various forms of made-up goods these sables today are literally worth a king's ransom. In the form of stoles, containing from fifteen to eighteen carefully matched skins, they have sold at prices ranging from $10,000 to $18,000.

A long coat of the finest quality Russian sables recently fetched $75,000.

As it is impossible for our fur trade to keep up with the demand for Russian sables, martin fur generally known as Hudson Bay sable, because it comes from Canada, is being put forward in competition with it, although costing considerably less, the best grade of this fur so closely resembles Russian sable that only an expert can tell the difference between the two. One of the most popular and reasonable in price of our strictly United States furs is muskrat. It is dyed and sold under the trade name of Hudson Seal. After a process known as plushing, which leaves only the soft, short under hairs, muskrat can be dyed so closely to resemble sealskin as to deceive the average person. So much in demand has it been of late that the market stands practically denuded of fine pelts suitable for seal dyeing.

Under the very broad name of furs not handled in our auctions, may be included the skins of almost all those animals which for the sake of protection against cold, have for a covering an under layer of soft, woolly, or downy texture, through which grows in most instances, an upper one of a more bristly or hairy nature; some by nature possess more of the under coat, and others more of the upper, the proportion varying considerably in different animals and countries. In winter the fur becomes thicker in its growth, thereby improving the quality and value for commercial purposes; young animals too possess thicker coats than full-grown ones. In some instances the under-fur alone is used in manufacturing, while the upper hairs are removed as in the fur-seal.

The present very general use of furs in all civilized countries had made the fur trade of the present day of much greater importance than in those flourishing days when the fur traders were the chief pioneers of the North American continent, and curiously enough the quantities of many fur-bearing animals have vastly increased, seemingly for the sole purpose of keeping up with the demand; especially is this true of those rather small mammals which seem to thrive and breed quickly in the proximity of settlements; the larger ones, on the other hand, such as bears, beavers, etc., will in course of time, if not protected become generally reduced

Photos by Gilliams Service

Eskimo hunters in their kyaks

A Hudson Bay fur trading post

in numbers, a fate which has overtaken the buffalo or North American bison.

Although large quantities of the smaller sorts are found in the United States, the chief supply of furs is obtained from Siberia and the northern parts of North America, and, as these tracts are for the greater part of the year frostbound, the fur-breaing animals enjoy a comparatively unmolested life; the fur, therefore grows quickly during the winter season, and is in its best condition when the animal is trapped in the spring.

The leading fur gathering companies today are the Hudson Bay Company, established in 1670, and the Alaska Commercial Company, in 1870. It is the furs of these firms together with large quantities consigned from numerous private traders that are offered at our fur auctions. Nearly all fur skins are brought to the market in the raw or undressed state.

The usual mode of dressing furs is by steeping them in liquor for a short time, after which the pelts are "fleshed" over a sharp knife, to get rid of the excess of fat, and subsequently dried off; they are next trodden by the feet in tubs of warm sawdust and common butter, by which means the pelt or leather is rendered supple; the skin is finished in dry sawdust, and beaten out. Certain furs, such as beaver, nutria, hare, and rabbit, are used in the manufacture of hats and other felted fabrics, for which purposes the under-fur alone is retained. It is cut off from the pelt, separated from the upper hair, and felted together by means of various machines.

Tempering Copper

THE following remarks upon the subject of tempering copper have been recently published by Lieut. Queunie of the French Army Engineer Corps, who is well known as a chemist and inventor. In view of the interest presented by this subject we will give his account in full. Because of the limited amount of knowledge possessed in ancient times, it is probable that they used a very simple tempering bath containing sea-salt and not pure chloride of sodium. However crude sea-salt is a mixture of chloride of sodium ,chloride of potassium, chloride of magnesium, and bromides and iodides of alkaline metals, It may, therefore, be asked which of these chlorides is really efficacious in the tempering process. The first stage in research work on tempering of copper would therefore consist in trying each of these chlorides separately, so as to determine this point. For each bath, it is also required to vary the strength of the solution, for this may have a marked effect, for aside from the chemical properties, the specific heat of the bath is a factor in the reaction, and it is known that this specific heat depends on the strength of the solution. Then trials could be made of baths containing two or three chlorides, for it is not proved that the tempering is not due to the action of two or more chlorides instead of one. If one of these tests should give a positive result but is still not very satisfactory, the field would at least be narrowed. Then all that would be required is to experiment so as to find the best amount of concentration, the temperature to give to the bath, and to the metal, and the time of immersion. It is supposed implicitly that in the case of copper, the tempering is due to a combination of the copper with the metal of one of the chlorides and that this combination lies on the surface of the metal under tempering. But is asked whether there is really a homogeneous combination upon all the surface. It may be supposed that the layer which has been tempered is made up of a juxtaposition of crystals of pure copper and crystals of an alloy of copper, also with alkali metal. When a sample is obtained, this point can be cleared up by microscopic examination of a broken place compared with pure copper. In any case, after finding the alkali metal which produces the tempering effect, it will be interesting to produce an alloy by fusion, and then to try tempering in pure water. This method will be the reverse of the preceding, and will give the advantage of obtaining a temper which is no longer on the surface, but concerns the whole mass of the metal by modification of molecular cohesion, if the alloy is to remain chemically homogeneous, or by formation of crystals in the contrary case. It will be easy to prepare such an alloy by melting copper in the crucible and then adding to the liquid metal a certain amount of carbonate of soda or of potash, or again, carbonate of magnesium. As the temperature of decomposition of these carbonates is that of a red-heat and therefore below the melting point of copper (or 1093 degrees C.), carbonic acid will be given off, followed by decomposition of the base (soda or potash), then alkali metal will be set free and will combine with the copper. Cover the surface of the bath with a few pieces of charcoal already in combustion, in order to reduce the oxides that may be formed. After stirring with an iron rod, remove the crucible, then run the metal into an ingot mold in sand, placed vertical and sufficiently high. By natural cooling, what is known as the liquation phenomenon may occur, and this will produce different combinations and crystalline or amorphous states, these taking place between the copper and the alkali metal. At the base of the ingot will be found the compound having the greatest density, and the lightest at the surface, this representing the eutectic alloy or the one having the lowest melting-point. Instead of carbonates, another method would be to use chlorides, whose decomposition would also occur at a red heat. The different compounds that might be produced by the liquation effect could be observed by the various superposed tints seen in the metal which is polished along one of the sides of the ingot. When these colors have been observed, the ingot will be divided into flat pieces according to the separation lines of the colors, and each piece will be tempered in pure water. Chemical analysis will then be made of the layers which show the required physical characteristics. This analysis will allow of observing the exact percentage of alkali metal, and hence it will be possible to reproduce the alloy by an industrial process and on a large scale. In order that no doubt should exist even should no success be had in finding a tempering bath, observations should be made on the following prepared test pieces in which the parts are given by weight.

A. Cu 98, Na_2 anhydrous CO_3 Na_2 = 4.602 or NaCl = 5.802
B. Cu 97, Na_2 anhydrous CO_3 Na_2 = 6.903 or NaCl = 7.623
C. Cu 95, Na_2 anhydrous CO_3 Na_2 = 11.505 or NaCl = 12.705
D. Cu 98, Na_2 anhydrous CO_3 K_2 = 3.530 or KCl = 3.782
E. Cu 97, K_2 anhydrous KO_3 C_2 = 5.295 or KCl = 5.673

It is to be remarked that in what precedes, we supposed the copper to be absolutely pure, and that such was the case in ancient times. But there was surely no copper refining process known in those days. In our time, metallurgical processes only allow of obtaining 97 or 98 per cent purity, and it is only electrolytic refining that will give 100 per cent. Again, copper is found in nature in the form of oxides, carbonate, phosphates, arseniates, sulphides, etc. It may be supposed that tempering can only take place in the presence of certain impurities. Phosphor bronzes, above three thousandths, are known to be brittle. Although arsenic is usually excluded from alloys, it may perhaps have a favorable influence as concerns tempering. An experiment should be made by preparing the following compounds in the crucible. A.—Cu 99, As 1. B.—Cu 97, As 3. The arsenic is to be incorporated into the bath in the shape of arsenious acid (As_2 O_3), and the above two formulas thus become: Cu 99, As 2 O_3 1.321 and Cu 97, As_2 O_3 3.963. Lastly, the question to be proposed is the following.

Is it desired to find a tempering process which is to confer certain physical properties on the metal, or do we wish to find a copper compound that has these same properties without having recourse to the tempering process? In fact, regardless of the specific process, what is wanted is to secure strength in the tensile sense, hardness, and elasticity.

Leaving the idea of tempering and turning to the search for an alloy, the author calls attention to tests to be made on alloys of the following composition which he considers would give the desired qualities of harness and elasticity and could perhaps be forged.

Copper	85	87	88	85	87	88
Tin	9	8	7	9	8	7
Manganese	5	4	3	..	..	..
Silicate of Soda	1	1	2	1	1	2
Antimony	..	..	..	5	4	3

The alloys using manganese are to be prepared in the crucible by first melting the copper and tin and then putting in the manganese in the form of protoxide (MnO) or sesquioxide (Mn_2O_3). At this moment, the temperature should be raised to 1,250 degrees C. Lastly, put in the silicate of soda in the finely ground state. In this way, the formulæ will become,

Cu	85	87	88
Sn	9	8	7
Mn O	6.455	5.164	3.873
or			
Mn_2O_3	6.940	5.552	4.164
Si O_3 Na_2	1	1	2

For alloys having antimony as a base, the order of melting is as follows: copper, antimony, tin, silicate of soda.

In closing, we will mention the composition of ancient bronzes. Roman bronze: Cu 99; Sn6; Pb6, for 111 parts. Greek bronze: Cu62, Sn 32, Pb 6, for 100 parts. This does not take account of the impurities, for the analysis is made only to show the amount of the three principle metals. The above experiments would take considerable time, but researches upon alloys have not established a safe theory which allows of predicting the physical qualities from the makeup of the alloy, hence it is necessary to resort to empirical methods, and these often give good results when the experiments are well carried out.

Controlling Dry Rot in Timber

IN a paper recently read before the Institution of Municipal and County Engineers, (London), Mr. E. J. Goodacre, in discussing the question of dry rot in timber, remarked that in dealing with cases where the presence of a serious attack of dry rot had been established, drastic action was necessary. The infected wood should, he said, be oiled to keep down the spores, and carefully removed and burned, and not deposited in a builder's yard. The carpenters' tools, especially the saw, used on the work should be sterlized. This might he said, appear to some to be rather too stringent, but the advisability of such a precaution was undoubted. The adjoining woodwork should be carefully tested and removed if there were the least signs of the fungi. The brickwork or stonework should be sterlized by a blast flame, and the woodwork should be dried—not by a gas jet, which formed moisture as a product of combustion—and treated with a wash of dilute formalin, which is a safe and most effective antiseptic, although it must be noted that through evaporation this treatment is purely temporary. Carbolic acid is also a valuable antiseptic for the purpose. Hot limewash is very useful for a mild attack, and, in fact, most antiseptics are more or less effective. In conclusion, Mr. Goodacre strongly urged that owing to the difficulty of completely eradicating the fungo when once established, preventive measures were of paramount importance.

National Fuel Research

THE greatly increased demands for fuel, caused by the extensive manufacturing operations necessitated for the production of enormous quantities of war material, together with those of friendly countries whose supplies have been interfered with by the war, have resulted in a shortage of coal in England, similar to that which the United States is experiencing; but conditions there are by no means as bad as here both because conditions of production have been more regular, and as the distances are much shorter, the problem of distribution is much simpler. Nevertheless, the necessity for economy, both at the present time and in the future has been recognized and a Fuel Research Board has been constituted by the Department of Scientific and Industrial Research, which is engaged in an exhaustive investigation with a view to strengthening the position of England in the commercial competition that is certain to arise on the termination of the war. A portion of a recent report by this Board is given below and it is suggestive of similar action that should be taken in this country.

In a previous report, which has not been published the Board stated that they had in view two main lines of research: (1) A survey and classification of the coal seams in the various mining districts by means of chemical and physical tests in the laboratory, and (2) an investigation of the practical problems which must be solved if any large proportion of the raw coal at present burned in its natural state is to be replaced by the various forms of fuel obtainable from coal by processes of carbonization and gasification.

At one time it was thought that the former line of inquiry could be proceeded with in advance of the second, but further consideration has shown them to be so interdependent that they can be most satisfactorily dealt with side by side. However, in preparation for the organization of the first line of inquiry, an experimental study of standard methods for the examination of coal in the laboratory has been made, and as the result of work carried out for the Board in the Fuel Laboratory of the Imperial College of Science a test has been elaborated which, by direct weighing and measurement, gives the yields of gas, oil, water, and carbonaceous residue that result from carbonization at any definite temperature.

PROBLEMS OF CARBONIZATION

Various influences during the last eight or ten years have led up to the second line of inquiry, including demands for cheaper and more ample supplies of electrical energy, for home supplies of fuel oil for the Navy and of motor spirit for the transport and air services, and for smokeless domestic fuel. The only development that would satisfy all these needs simultaneously would be the replacement of a large proportion of the raw coal which is at present burned in boilers, furnaces, and domestic fires, by manufactured fuels prepared from raw coal by submitting it to distillation. A certain amount of knowledge and experience is in the possession of experts, who might be able with its aid to organize and direct schemes for replacing raw coal by manufactured fuel in certain directions and on a fairly large scale, but no really comprehensive scheme can be formulated until certain perfectly definite problems in coal distillation have been solved.

The gas retort and the coke oven have become highly developed appliances for the carbonization of coal at temperatures ranging from 900 to 1,200 deg. C.; accordingly, for such high-temperature methods of carbonization a great amount of experience is available, and trustworthy data on which to base the calculation of the economic possibilities are in existence. But for the carbonization at lower temperatures there is no corresponding body of experience, and very few properly accredited data are available; for, although the low-temperature distillation of oil shales for the production of mineral oils, paraffin wax, and ammonia is a highly developed industry, the oil shales are totally unlike coal in their nature and the products they yield, and experience gained in that industry is only indirectly useful so far as coal is concerned. Of the experience gained in low-temperature carbonization of coal by individual inventors and syndicates only portions have been disclosed, but enough is known to justify the conclusion that much still remains to be done in devising the special forms of apparatus required for carrying out this type of carbonization. The way is obviously open for a serious attempt to determine whether economical and efficient apparatus can be devised for this purpose, and whether, by using properly selected coals in such apparatus, products will be obtained of a collective value greater than that of the original coal plus the cost of carbonization and handling.

QUESTIONS TO BE ANSWERED

The solution of these fundamental problems will supply a new base from which to attack such questions as the following:

(1) Can the 35 to 40 million tons of raw coal used every year for domestic heating be replaced wholly or partially by smokeless fuel, solid or gaseous, prepared by the carbonization of this coal?

(2) Can adequate supplies of fuel oil for the Navy be obtained by carbonizing the coal at present used in its raw form for industrial and domestic purposes?

(3) Can supplies of town gas be obtained more economically and conveniently by methods of carbonization and gasification other than those now used in gas work?

(4) Can electric power be obtained more cheaply if the coal used for steam raising is first subjected to processes of carbonization and gasification?

(5) Will the more scientific development of the preparation and use of fuel, which would be implied in the successful working out of the forgoing questions, enable the peat deposits of the United Kingdom to take a serious place as economic sources of fuel for industrial purposes?

(6) Can the use of gaseous fuel in industrial operations be forwarded by the development of more scientific methods of combustion in the furnaces, muffles, and ovens used in metallurgical, ceramic, and chemical operations?

Answers to these questions, the report points out, will be obtained only by co-ordinated research carried out on the lines of a broad and well-considered scheme; but at the same time the Fuel Research Board think it is to be expected that solutions of some of the problems will be supplied by workers in the industries, and they would regard it as a great misfortune were the establishment of a Government organization for fuel research to result in discouraging or in any way limiting the activities of outside workers or organizations.

DISPOSAL OF PRODUCTS

Even if an efficient method of low-temperature carbonization is evolved it will be valueless in the wider sense unless profitable outlets for all the important products can be developed; and the Fuel Research Board, being in official touch with the Admiralty, the Ministry of Munitions, the Board of Trade, and other public Departments, are exceptionally well placed for the furtherance of schemes that entail the finding of large outlets for products new and old. For instance, since the Admiralty attach great importance to the development of supplies of fuel oil from home sources, this requirement alone would absorb all the oil which could be produced by the carbonization of tens of millions of tons per annum. This fact alone gives an entirely new aspect to the extension of carbonization in hitherto untried directions, but while it will undoubtedly help on the economic side of the problem it does not relieve the pressure on the technical side. In a way, moreover it accentuates the problem of the profitable disposal of the coke which is left when the voltile products have been distilled off the coal. On the average it may be taken that each ton of coal carbonized will give 15 cwt. of coke; hence from the 20 million tons of coal which would have to be carbonized in order to obtain one million tons of fuel oil for the Navy 15 million tons of coke would be produced.

The disposal of this large quantity of coke at a profitable price must be regarded as the vital question if low-temperature carbonization is to be established on a sound economic basis. The research scheme must therefore include a very complete inquiry on the use and value of this coke for the direct firing of steam boilers, its gasification in producers for the manufacture of low-grade fuel gas and the recovery of its nitrogen as ammonia, and its use for industrial and domestic heating, either directly as it comes from the retorts or after conversion into briquettes. The second of these inquiries will involve the development of a special form of gas producer and auxiliary plant if the best results are to be obtained, and also of a system of boiler firing in which fuel gas of low calorific value can be burned at least as efficiently as coal, both as regards thermal efficiency and the effective evaporation per square foot of heating surface.

The use of the lower grades of fuel gas, though successfully carried out in certain directions, is very imperfectly understood in the majority of industries in which gas might be used for heating and power purposes, and here there is scope for much useful work, both in research and in the education of experts and consumers. Again, though the use of town gas as a fuel for industrial purposes has made great strides during the past few years, actual practice still lags a long way behind the ideals of economy and efficiency.

ELECTRIC SUPPLY AND CARBONIZATION

As an illustration of the complicated inquiries which will have to be conducted before an answer can be given to what seems a simple question, the report refers to the suggestion that the cost of producing electric power from coal in this country would be substantially reduced if the coal, instead of being burned directly under the steam boilers, were first subjected to carbonization and gasification processes which in addition to fuel gas would yield valuable by-products. Plausible statements, it is remarked, have been issued showing the enormous savings or profits which would accrue if schemes of this sort were adopted. Unfortunately these estimates have generelly been made on a very slender foundation of knowledge and experience. On the other hand, those who by experience and practice are best qualified to judge, hesitate to prophesy as to what the economic result of a combined carbonizarion and power-generating scheme would be, but they agree that the interests at stake are so great that the question ought to be authoritatively answered once for all. But no answer can be accepted which is not founded on the complete working out of the scheme, no important step in the series of operations being omitted or slurred over. This series of operations will start from the mechanical preparation of the coal and its conversion into solid, liquid and gaseous products by carbonization. It will end with the delivery of a known weight of high pressure steam under the conditions most favorable for power production by turbo-generators. In the proposed scheme of research the investigation of each of the steps involved in the above inquiry is provided for. Three, at least, of these steps involve pioneering work on an industrial scale, and the work may occupy a considerable time. It is possible that the net result of this particular inquiry may be to show that purely as a means of cheapening the cost of electric power the use of carbonization methods has not much to commend it, but will be justified by incidental advantages in particular cases.

THE EXPERIMENTAL STATION

The scheme of research outlined in the report cannot be efficiently conducted, it is declared except in a fuel research station designed and equipped for the purpose, in which operations on an industrial scale can be carried out under proper working conditions. It being realized that the conditions required by such a station could be fulfilled only by a site in the neighborhood of a large gas works, the Director of Fuel Research approached Dr. Charles Carpenter, the chairman of the South Metropolitan Gas Company, some months ago, and subsequently Dr. Carpenter, on behalf of the directors of his company, made the following very generous offer:

(1) To lease to the Government at a peppercorn rent sufficient land at the East Greenwich Gas Works for the erection of the research station.

(2) To prepare drawings and specifications for the station on lines laid down by the Board, and to make contracts for its erection.

(3) To give every facility for the transport of coal and other supplies to the station and to take over at market prices the surplus products, gas, tar, liquor, and coke, resulting from the operations of the station.

The site consists of a strip of level ground, about 250 ft. wide by 700 ft. to 800 ft. long, situated on the main siding which connects the gas works with the South-Eastern Railway and possessing access to an existing road.

PROPOSED EQUIPMENT

The following description is given of the equipment which will be required for the research work at present in view: A railway siding will pass through or by the side of the station, and the coal to be used in tests will be received in railway wagons at an unloading platform provided with a sampling floor, a coal breaker and screens, a weighing machine, an elevator, and high-level bunkers. From this the coal will be passed on to the retort house, where ample space will be provided for the erection of the various forms of carbonizing apparatus which are under investigation. Facilities will be provided for quickly carrying out the necessary changes and improvements in the apparatus as the experimental work proceeds. The hot gases will be led from the retort house into the condenser and exhauster house, which will be equipped with condensers, washers, scrubbers, exhausters, compressors, meters, pressure regulators, gages, pumps, motors and tanks. For the collection and examination of the gases in bulk gas holders will be provided. The hot coke from the retort house will be elevated to high-level bunkers, from which it can be supplied to gas producers, steam boilers, briquetting plant, or railway wagons. The gas producer house will be provided with one or more gas producers, with heat exchangers, washers, scrubbers, and liquor tanks; the steam boiler house with one or more water-tube boilers of modern type, and with feed water tanks, water and steam meters, pumps, etc., and the briquetting house with

grinding, mixing, and briquetting machines. Tar and oil stills and condensers will be provided for dealing with the liquid products, and the gas furnace house will be equipped for the testing of gas muffles, annealing ovens, and melting furnaces. The station, as planned, will be capable of any extensions required for future researches.

The scheme of research described is not intended to cover the whole of the territory open for exploration today. Still less ought it to be regarded as setting any limits to the exploration of new territories in the future. The root idea of the scheme is that certain fundamental changes in the preparation and use of fuel which have been proposed are of such far-reaching importance that the solution of the technical and economic problems involved ought to take precedence of all other matters. This does not mean that other lines of research will be ignored, but only that the larger issues must be kept well to the front till definite solutions of those technical and economic problems can be given. Though no direct reference is made to the preparation and use of fuels from oil shales, brown coals, and peat, experimental inquiries on these matters will naturally find a place in the developments of the scheme.

A Zeppelin Surprise

By Jhadoo Jahaz

MANY interesting points arise out of the raid of October 19th and subsequent events, not the least of which is the extraordinary height to which the airships attained. The writer has been endeavoring to arrive at some figures of lift and weights which would enable the airships to land more or less in equilibrium, after reaching 20,000 feet, and the results of those calculations are given here in the hope that they may prove of interest. It must be remembered, however, that it has been largely working in the dark and the figures are not put forward as in any way to be relied upon, but they may at any rate give some idea of the magnitude of the achievement and of the enormous strides in airship design which have been made during the war.

Following the ordinary formula, which is only an approximation, that an airship loses one-third of its lift for every 1,000 feet risen, at a height of 20,000 feet two-thirds of the gross lift will have been lost through the expansion of the gas. In an airship of 2,000,000 cubic feet, having a gross lift of sixty tons, this amounts to forty tons, which means that the fixed weights must be no more than twenty tons. The next step in the calculation, then, is to draw up a table of weights in the endeavor to keep them within the limit of twenty tons.

Mr. Warner Allen, who has produced the only approximately accurate description of the airships, states that the weight of the "structure" is ten to twelve tons. Using this as a basis and acting on the assumption that by "structure" he refers to the hull framework—when the figure appears reasonable—we arrive at the following estimated table of weights:

	Tons
Hull framework	12
Outer cover, gas bags, etc.	5
Planes	1
Framework of cars	1½
Power plant (five engines, gearing, propellers, etc.)	2½
Fuel tanks	1
Armament, wireless, etc.	½
Miscellaneous weights	1
Total	24½

If these weights are correct—and it is difficult to see how they could be reduced, as they err rather on the side of lightness—judging by the rough approximation given above, an airship of this type cannot rise to 20,000 feet, even when unloaded, or, to be more precise, it cannot rise *statically* to that height, though it could probably be forced up by means of the elevators, but on coming down again it would be too heavy to allow of a safe landing being made. As the information of the height reached is so very definite and given on such reliable authority, it is desirable to check the result by adopting more precise methods of calculation. The variable factors which affect the lift, and therefore the performance, of an airship of given volume and weight are:

(1) The purity of the hydrogen with which it is filled.

(2) The atmospheric pressure, shown in inches on the barometer.

(3) The temperature.

The theoretical lift of pure hydrogen is 71.55 pounds per 1,000 feet, at normal temperature and pressure (N. T. P.), but it is usual to calculate on the basis of the hydrogen containing 5 per cent of air or other impurities —*i. e.*, being 95 per cent pure. This represents a lift of 68 pounds per 1,000 cubic feet. Normal barometric pressure is usually taken as being 30 inches on the ground, it being subject to a fall of approximately 1 inch per 1,000 feet of ascent. On the night of October 19th the barometer on the ground was almost the standard, so that we can assume that the pressure at 20,000 feet would be 30—20 = 10 inches.

With any gas a change in the temperature is accompanied by a regular corresponding variation in the volume of the gas. At a temperature of 460° Fahr. the limit is reached below which no further contraction can take place, and this point is known as *absolute zero*.

To find the corresponding Absolute temperature for any temperature on the Fahrenheit scale, all that is necessary, then, is to add or subtract 460° to the Fahrenheit temperature, according to whether the temperature is above or below zero (Fahrenheit). The "Normal" temperature is 60° Fahr. or 520° Absolute. According to the extracts published from the log-book of L.49, the lowest temperature recorded—which would be presumably at the maximum height reached—was −30° Fahr. or 430° Absolute.

The two last variables depend upon the law—familiar to chemists—known as Boyle's Law, which states that the volume of any gas varies directly with the pressure to which it is subjected—or, in other words, a *fall* in temperature and a *rise* in pressure reduce the volume of gas, and *vice versa*.

We have now arrived at a decision as to the conditions prevailing at the time of the raid regarding each of the three variables, and will therefore formulate our equation on the assumption of a hydrogen purity of 95 per cent, barometric pressure of 10 inches, and absolute temperature of 430°. The lift of an airship per 1,000 cubic feet of its volume in any given condition will be: Theoretical lift of pure Hydrogen (71.55) × Actual purity of Hydrogen per cent × Actual bar. pressure × Normal Absolute Temperature.

$$\frac{(520)}{\text{Normal bar. pressure (30)} \times \text{Actual Abs. Temp.}}$$

Substituting we get:

$$71.55 \times \frac{95}{100} \times \frac{10}{30} \times \frac{520}{430} = 27.4 \text{ lbs.}$$

Under the conditions prevailing then, the lift of the airship per 1,000 cubic feet would be only 27.4 lbs., and the gross lift would have fallen (the volume being 2,000,000 cubic feet) from 60 tons on the ground to 24.5 tons. This figure, it will be seen, exactly coincides with our estimated total of the weight of the airship itself without any crew, fuel, or bombs. The bombs would have been dropped before the airship reached its maximum height, but at least half the petrol would remain unexpended, and, of course, the weight of the crew would remain in the cars.

For a journey of this nature the crew would probably number 20—aggregating 3,200 pounds—and fuel for 20 hours at least would be carried. Five 240 horse-power Maybach engines would consume (at 0.5 pounds per horse-power per hour) about 600 pounds of petrol per hour. The airship would carry then about 12,000 pounds of petrol, of which some 4,200 pounds would have been consumed during the eight hours' flight to London. We are, therefore, forced to the conclusion that the airship would be too heavy by some 11,000 pounds (the weight of the crew plus the unexpended petrol) to rise statically to 20,000 feet when over London. On the rough basis that 1.30 of the lift is lost for each 1,000 feet risen, this 11,000 pounds represents a height of:

$$\frac{11{,}000}{134{,}400 \text{ (60 tons)}} \times 30 = 2{,}500 \text{ ft.}$$

This distance the airship could easily cover by "planing" up under the influence of the elevators. She would, of course, still be 11,000 pounds heavy on coming down, again, but on landing the captain would drop any petrol remaining and land "heavy" by the precise amount of the weight of the crew. As this is only about 1½ tons, the operation should not be difficult with a good pilot, particularly if he were landing into the hands of a trained landing party.

It would appear from the foregoing that the latest type of Zeppelin is designed to be able to attain a height of 17,000 to 18,000 feet when over its objective, and after dropping its bombs, but is capable of going even higher under stress of circumstances and at the risk of suffering some slight damage on returning to its base. These conclusions accord well with Mr. Warner Allen's statements that these airships "are built with a view to flying at between 16,000 and 18,000 feet." Of course, on a short flight they could go higher in view of the reduced quantity of petrol to be carried.

One statement from the above-named source requires some explanation. It will be seen that if the total of fixed weights given earlier in this article be deducted from the gross lift of 60 tons, 35½ tons are avialable for "disposable weights," such as crew, fuel, bombs, and water ballast. Of this 1½ tons are taken up by the crew and 5½ tons by fuel. Mr. Allen states that the maximum of bombs that can be carried is 2½ tons. If this be so the Zeppelin must carry in the neighborhood of 26 tons of water ballast, which seems excessive in view of the fact that a considerable portion of this weight, at any rate, might be allotted to bombs, which may be looked upon as ballast as they can be dropped at any moment required when over the sea or hostile territory.—*Aeronautics*.

Temperature of Liquid Steel

IN his paper on "The Determination of the Temperature of Liquid Steel under Industrial Conditions," at a recent meeting of the Faraday Society, reported in *Engineering*, Mr. Cosmo Johns, F.G.S., M.I.Mech.E. of Sheffield, pointed out that there was a marked thermal effect when liquid steel issuing from the tap hole of an acid open-hearth was succeeded by the first flush of slag. Viewed through blue glass the slag was much brighter than the steel. The steel would reflect the light of the sun or an arc lamp, while the slag was less efficient as a reflector; as good reflectors were poor radiators, the differences in emissivity had to be taken into consideration. The thermal effects could be studied with a Féry radiation pyrometer, but marked corrections had to be made when different parts of the stream of metal were in the field. Optical pyrometers for monochromatic light had proved most useful, provided special precautions were observed; that experience agreed with the experience of Dr. Burgess in American steel works. The liquid steel was best observed from a distance of about 12 feet at nearly a constant angle, and to avoid fumes, from the clear side to the windward of the stream. Experienced observers could estimate temperature differences of 15 degrees and even 10 deg. C. merely by watching the steel through blue glass as it was poured into the ladle. Pyrometers should be able to give higher accuracy, and trained observers could indeed obtain readings agreeing within ± 2.5 degrees or ± 5 degrees at any rate. For each particular casting method of a class of steel it was only necessary to determine the "normal" temperature when the steel was tapped from the furnace; deviations from the normal by more than ± 10 degrees were avoidable in practice, at least for special steels.

As regards the temperature distribution in the furnace hearth, there was a layer of, say, 4 inches of liquid slag between the flame and the liquid steel, 15 inches deep, and all the heat had to pass through that layer which was therefore hotter. In correcting the apparent temperature readings, assumptions had to be made for the emissivities. The surface layer of slag consisted of fused iron peroxide, which Mr. Johns supposed to have an emissivity of 0.50; the emissivity of the liquid steel was probably 0.40. Insertion of a patch of new silica brick in a seasoned wall might make a difference of 20 degrees. Observations indicated that there was a temperature gradient in the liquid steel bath, which could be estimated by observing the stream, first of steel and then of slag, as it flowed from the taphole into the launder. As regards thermal losses there was a sharp drop in the readings when the clean surface of the steel in the ladle was compared with the stream flowing from the tap hole: but once the steel had been covered by its protecting layer of slag, after five minutes, the thermal losses rapidly diminished. That workmen could so well control a furnace temperature was partly accounted for by the fact that the open-hearth, fed with producer gas of regular composition, was of a constant temperature, hotter than the walls, and acted itself as a pyrometer.

Absorption of Ultra-Violet Rays

MESSRS. MASSOL AND FAUCON have been engaged in a series of interesting researches concerning the absorption of ultra-violet rays by the halogen derivation salts of methane, and they studied four salts containing iodine; CI_4, CHI_3, CH_2I_2 and CH_3I, either pure or diluted with absolute alcohol, comparing spectrum results with those obtained with iodine in solution in the same alcohol. They find that the present bodies have the selective absorbent properties of iodine, but considerably modified as to results so that each of these bodies shows a spectrum of a particular character.

Future Trans-Sahara Route

THE recent 1,200 mile trip across the Sahara which was recently made by M. Bonamy, Administrator of Colonies, is of interest both from a political and an economic standpoint. It is in fact important to establish the connection between Algeria across the Desert to the French possessions in the region of Timbuctoo and on the Niger. One point is to explore the route for the passage of troops across the desert, then it is also proposed to organize an automobile service, and this will be especially valuable for postal matter. The last trip across the desert was made six years ago from Algiers to Timbuctoo by way of In-Salah by M. Le More, a French official.

Some Factors In Illuminating Engineering*

The Production of Visual Sensations

By Professor F. K. Richtmyer†

ORDINARILY *"seeing"* involves or implies at least four distinct, but more or less interdependent, processes, each one of which is absolutely essential to the final visual sensation.

(1) There must be a source—usually called a primary radiator—which produces what we shall hereafter call "light energy" (or more simply, "light"), *i. e.*, radiant energy of such wave lengths as are capable of producing a visual sensation on the retina.

(2) This light must be transmitted directly or indirectly by means of suitable media—such as reflectors, shades, globes, reflecting surfaces, etc.,—to the surface (or object) which we desire to see.

(3) In order that this surface may be visible, the light falling on it must be reflected to the eye of the observer.

(4) Where, by a very complicated mechanism, the (physical) light energy is transformed into a visual sensation.

It is evident that failure in any one of these steps must result in an absence of visual sensation—in short, we can practically say that there can be no illumination.

The production of illumination, therefore, involves a study of each of the four processes just mentioned. Very briefly it may be said that two or three decades ago the man who would have been called an illuminating engineer, had the term been in use then, concerned himself almost entirely with the production of light; with getting more light from a given amount of power; he paid comparatively little attention to the distribution of the light to the surfaces to be viewed. A decade or so ago, the question of the proper use of shades, globes, and reflectors so as to produce a maximum of light flux onto the area to be viewed was recognized as of almost equal importance as the question of how to get the most light from a given source. A system using the most efficient light sources, but making poor use of the light after it is produced is no better as to net efficiency than a system which employs less efficient sources but which carefully distributes the light produced to the "working plane." Today, the attention of the illuminating engineer is directed not only to these two, but to the fourth item mentioned above, namely to the physiological factors in the science of lighting. It is this latter phase of the "science and art of illumination" which will be taken up in the present article.

Fig. 1 shows the essential parts of the eye. By means of a lens system an inverted image of the object viewed is formed on the retina (8). A highly magnified section of the latter shows it to consist of a number of distinct layers, the outermost of which is a layer of rods and cones (so-called from their shape) arranged "palisade" fashion, and pointing toward the external part of the eyeball. These rods and cones may be regarded as nerve ends, which, in some manner not at all understood, are stimulated by light, thus causing the sensation of vision.

SOME FACTORS IN VISUAL SENSATIONS

Visual sensations are dependent on several factors: (1) the intensity of the light energy (physically measured in, say, ergs per second falling on a square centimeter of retina surface); (2) the wave length (color) of this light energy; (3) the condition of the eye as to: (a) adaptation and (b) immediate previous history.

Sensation and Light Intensity.—Keeping all other factors (both physical and physiological) constant, the visual brightness of an illuminated surface is roughly proportional to the logarithm of the (physical) energy flux on that surface. That is, we would judge one surface to be twice as bright as another, if the flux of energy on the first is *ten* times as great as the flux of energy on the second. (This holds true only over a limited range of brightnesses.) The practical significance of this is that brightness sensations increase at a much less rapid rate than the energy flux which causes them. If the intensity of illumination for a given purpose be just sufficient, there is little to be gained by a further increase in brightness. A bridge engineer determines carefully the stresses which each member of his bridge will be called on to sustain, and adjusts the size of the member accordingly. A lighting engineer must know what intensity of illumination is required for a certain purpose. Any undue increase in this intensity is not only wasteful, physically, but may be harmful physiologically.

Sensation and Wave Length of light.—Every one who has seen a spectrum has observed that it is brightest in the yellow-green; that the brightness gets less as we go toward either the red or the blue end. Suppose it were possible to project on a screen a spectrum which should appear (to the eye) equally bright from the red to the violet. If, by means of a sensitive device as a thermopile or bolometer, we were to measure the energy flux at each color (wave length) we should find that the *distribution of energy* throughout the spectrum to produce equal sensations of brightness would be essentially as indicated in Fig. 2; A, if the intensity be high (such as is ordinarily used in daylight illumination); or as in B if the intensity be low (moonlight). The ordinates are of course in relative units only. It is to be noted (curve A) that one watt spent in producing yellow-green light is just as effective in causing a visual sensation as, say, 6 watts spent in producing red light. Conversely, if the spectrum had the *same energy* (power) at each wave length the *brightness distribution* would be as indicated in Fig. 3. This curve shows the relative sensibility of the eye to the various spectral colors and is known as the "luminosity curve," since, as above stated, it shows the relative luminosity throughout an "equal energy" spectrum.

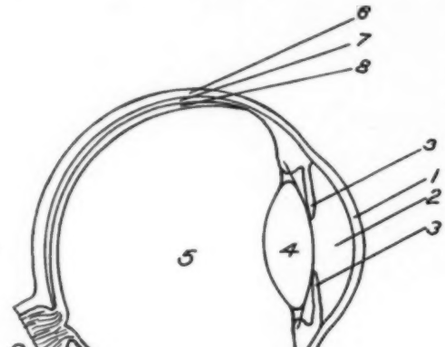


FIG. 1. THE EYE.

1. Cornea.
2. Anterior chamber (aqueous humor.)
3. Iris.
4. Lens.
5. Vitreous.
6. Exterior layer (sclera)
7. Middle layer choroid)
8. Inner layer Retina).
9. Optic nerve.

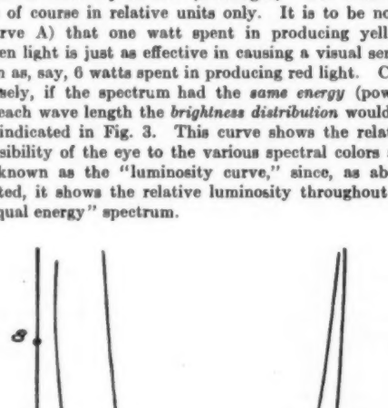


FIG. 2. Showing relative energies necessary to produce the same brightness; *A* for light intensities; *B* for low intensities.

Now, the energy distribution in the spectra of our artificial illuminants is of course far from uniform. Not only is the larger part of the energy radiated found outside the visible region (*i.e.*, in the infra-red) but in the visible part of the spectrum there is a far larger proportion of energy in the red end of the spectrum than in the blue end. Fig. 4 A, shows the energy distribution throughout the visible spectrum of a tungsten lamp. It is evident that if the ordinates of Fig. 3 be multiplied by the ordinates of Fig. 4A the resultant curve, Fig. 4B, will give the brightness distribution throughout the spectrum of the tungsten lamp. It is to be noted that the maximum brightness appears near the yellow. In the brightness distribution for equal energy (Fig. 3) the maximum appears near the green. That is, tungsten light is yellow as compared with the light of equal energy distribution, the nearest approach to which is daylight.

A light source which radiates all its energy at the maximum of Fig. 3, *i.e.*, in the yellow-green, would be the most efficient source possible, since its energy comes at the place of maximum sensibility of the eye. If we call the efficiency of such a source 100 per cent, the efficiencies of some common illuminants are shown below:

INCANDESCENT LAMPS

	Per cent
Carbon	0.4
Tungsten (vacuum)	1.4
Tungsten (gas)	2.8

ARC LAMPS

	Per cent
Carbon	1.9
Magnetite	3.5
Yellow flame	7.0
Mercury (glass)	3.7

FLAMES

	Per cent
Gas (common)	0.04
Petroleum	0.04
Acetylene	0.1
Welsbach	0.3

From the above it is seen that the extremely low efficiencies of artificial sources *is due to the physiological peculiarities of the human eye* rather than to the inefficiency of the sources as radiators, in that the eye is sensitive to only a very limited spectral region, a region in which, perhaps unfortunately, these sources radiate only a small part of their energy. (It is interesting to note that the maximum energy in the spectrum of daylight comes very near the maximum sensibility of the eye—a point of interest to the student of evolution.)

VISUAL SENSATIONS AND THE CONDITION OF THE EYE

Adaptation.—Every one is familiar in a general way with the phenomena of adaptation. On coming from bright sunlight (especially from a snow field) into a dimly lighted room, we can at first see scarcely anything. However, after a time, the length of which depends on the difference between the two intensities, in doors and out, our visual functions return to normal. The converse appears when going from a darkened room into light. In this case the process of "adaptation" takes place much more rapidly, although with a painful sensation if the change in brightness be extreme.

There are two distinct phenomena concerned in the process of adaptation. (1) In going into a brighly lighted room there is a contraction of the pupil of the eye, or an expansion when going from the light room into the darker room. Only a few tenths of a second are necessary for this change in pupil area, the effect of which is to adjust the brightness of the image formed on the retina just as the "stop" in a camera adjusts the brightness of the image on the photographic film. (2) The sensibility of the retina changes, becoming less sensitive as the light intensity becomes greater, *i. e.*, as the intensity of illumination increases a *given brightness* of retinal image will produce a weaker visual sensation. —again just as a very sensitive photographic plate is used for a "weak" light, whereas a less sensitive one may be used for bright daylight. These two processes are referred to respectively as "pupillary adaptation" and "retinal adaptation."

It is by means of this process of adaptation, little if at all understood physiologically, that the eye is able to accommodate itself to the extreme ranges of brightness from noonday to moonlight—a range of 1,000,000 to one, and yet the eye can see fairly well in either case, provided it be allowed to "adapt" properly.

*One of a series of articles published in the *Sibley Journal of Engineering*, Cornell University.

†Professor Richtmyer, of the Physics department of Cornell University, is Chairman of the Committee on Education of the Illuminating Engineering Society, and a member of the Research Committee under whose auspices he made some extensive investigations this past summer at Washington, D. C., in conjunction with U. S. Bureau of Standards.

There is, however, an upper limit of brightness beyond which the eye cannot see with comfort, *i.e.*, for which it cannot adapt. Which means, that the sensation produced by the light action becomes excessively great. One might compare the eye, exposed to such conditions of extreme brightness, to a muscle suddenly called upon to do work far in excess of its customary activity. The muscle gets fatigued and may be permanently injured. So with the eye. Every one has experienced the pain accompanying continued exposure to a snow field on which the sun shines brightly. The processes which transform radiant energy into visual

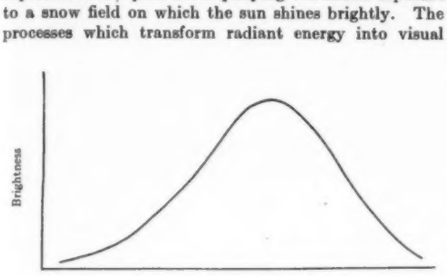


FIG. 3. Showing the apparent brightness at the various parts of an "equal energy" spectrum.

sensation are continuously over stimulated. The eye cannot adapt to that high level of brightness, and we have a condition known as "continuous brightness *glare*" as contrasted with the "temporary brightness glare" which we experience in going from a dark room to a lighter one. It happens that the upper limit of brightness to which the eye may be safely exposed is about that of the oil or gas flame. Brightnesses in excess of this, such as the tungsten lamp filaments, various arc lamps, etc., when viewed directly, are injurious because of the excessive stimulation of the part of the retina on which the light falls.

This process of adaptation automatically adjusts our visual sensations to the "general level" of the illumination in which we find ourselvs. In the light of the noonday sun, we say that one piece of paper is black and another white. We make the same distinction under average artificial illimination. Yet the amount of light reaching the eye from the "black" paper in daylight is many times that reaching the eye from "white" paper at night. The "blackness" or "whiteness" of an object does not depend so much on the quantity of light energy reaching the eye, as on the condition of the eye receiving it. By properly adapting the eye, it is quite possible to deceive it into judging the black paper in daylight *to be white*.

As a practical example of the importance of this phenomenon of adaptation may be mentioned the following: The reading room of a certain city library was brilliantly (though poorly)! lighted. The hall and entrance were still more brilliant. Frequent complaints were made to the director that there was not enough light in the reading room. After much study the director decided to try an experiment. He reduced the illumination in the hall and entrance below the general level of that in the reading room. Complaints immediately ceased.

The process of adaptation does not seem to call for any great physiological effort, yet it is injurious to adapt from a low level to a high level and back again, many times in more or less rapid succession. Thus, if one's desk be well lighted, but the rest of the room be much darker, the eye must readapt whenever the gaze is directed from desk to room, or *vice versa*. If this be repeated many times, serious ocular fatigue may result. The room should be somewhat less brilliantly illuminated than the desk, but the difference should be comparatively small. In other words, excessive brightness contrasts over comparatively large (visual) areas of the field of view are to be avoided. Some contrast, however, is desirable to rest the eye—just as a certain amount of movement rests a muscle. There are objections of the same kind to the lighting of a dining room by means of a "dome" which causes a brilliant illumination on the white table cover, but leaves the remainder of the room in comparative darkness, necessitating a readaptation of the eye whenever one looks from the table to other parts of the room. In general whenever the imagined artistic requirements of decoration conflict with the physiological requirements of hygienic illumination, the former should be disregarded.

GLARE

Bright light sources within the field of view in addition to causing the injurious effects mentioned above, seriously interfere with comfortable vision. This is due to three causes: (1) Excessively bright areas, even though small as compared with the whole field, will cause a contraction of the pupil, thereby reducing the (physical) brightness of the retinal image. (2) The eye media cause a slight scattering of the light from the bright source, producing the well known "foggy" appearance which surrounds the source. (3) But more important than either of these is the shifting of the state of adaptation toward that required for the brighter area, and a consequent (apparent) darkening of the visual field immediately surrounding the source, just as the interior, of a house appears dark compared to full sunlight. Extreme examples of this effect—the interference with vision caused by the automobile headlight, or an isolated street lamp—are well known to everyone. But the extent to which conditions met (too frequently) in ordinary interior illumination interfere with good vision is perhaps little appreciated. Thus the actual ocular discomfort or injury which arises from a high-candle power source in the field of view is largely eliminated by surrounding the source by a suitable duffusing globe, or even by frosting the lamp. But the interference with vision is not materially reduced unless the area of the globe be large enough to bring the brightness of its surface down to the general level of the surrounding illumination. It has been shown that the interference with vision due to such excessively bright areas is roughly proportional to the square root of the total candle power. The position of the light source in the field of view is also of importance. Sources located 30 degrees or more front the direct line of vision do not cause serious annoyance.

AFTER IMAGES

The intensity and quality of our visual sensations are dependent on the immediate previous exictation of the retina. Everyone is familiar with the phenomenon of after images. If one looks steadily for several minutes at a bright red book cover and then shifts the gaze to a white wall the wall will appear *green* over the visual area previously occupied by the book.

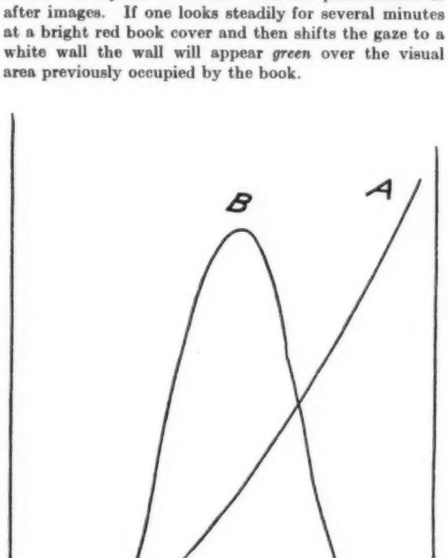


FIG. 4. *A*, showing the distribution of energy throughout the (visible) spectrum of a tungsten lamp; *B*, the luminosity of the spectrum of a tungsten lamp.

Physically the light which enters the eye from the wall, and falls on that part of the retina previously "fatigued" by looking at the red book, is white light. But, on account of the immediate previous excitation of the retina it gives rise to the *sensation* of green. If one had had only just that fleeting glimpse of the wall one might have been ready to testify to a jury that a *green patch* was seen on the wall.

The same phenomenon occurs on looking steadily at an extremely bright area. On redirecting the gaze to the white wall one sees a dark patch over that part of the visual field formerly occupied by the bright area. In fact, it may be said that in general bright areas within the field of view of such an intensity as to leave persistent after images are harmful.

The study of after images is perhaps of only minor importance in the study of illuminating engineering, and yet it serves to impress us very forcibly with the complicated nature of visual phenomena, and perhaps may pave the way for a clearer understanding of the immediate causes of, and the methods of eliminating, those various ocular difficulties which result from even the best artificial illumination. Fig. 5 will show the complexity of the visual sensation that arises from exposing the eye to light for a few tenths of a second.

It is impossible to discuss in an article of this scope a large number of important physiological phenomena, more or less closely connected with the science of illumination—such as the effect of ultra-violet and infra-red

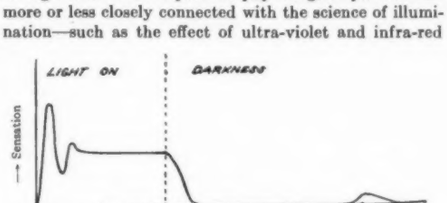


FIG. 5. Showing the fluctuation in the visual sensation resulting from an exposure of the eye to light for 0.2 seconds.

radiation on the eye; of the discomforts, both physiological and psychological, which result from a flickering illumination, with its reflex action on the eye muscles; or of the loss of power to adapt due to "sun blindness" or "desert blindness," and the like. It is sufficient, perhaps, to have called attention to the fact that the primary object of illumination is to cause, in a great variety of forms, a visual sensation and that a complete study of the science involves careful attention to the phenomena of vision. Failure to take proper account of these factors in illumination would place the illumination specialist in the class of a power engineer who might know all about mining and distributing coal, but who paid no attention to the boiler and the engine, which are the things for which the coal is needed, and without a thorough knowledge of which little progress in motive power could be accomplished. The production and distribution of light simply serve to "operate" the eye, without which vision is impossible!

Vaccination for Tetanos

IT is observed that iodine has a neutralizing action upon the tetanos poison, and transforms it into a complex body of a new composition, this being neutral and hence harmless for the organism and can be used for vaccination. Messrs. H. Valleé and L. Bazy find that when the iodized toxines are employed, it is possible to vaccinate animals which are as sensitive as the rabbit or the horse, and the results are excellent. This led to vaccination of persons. The toxine employed is such as will be fatal for guinea pigs in the amount of one 10,000 of a cubic centimeter. The neutralizing iodine solution is made up of one part iodine and two parts iodide of potassium to 200 parts water. They treated a number of persons with successful results. Used upon rabbits, the vaccination protection holds good under a dose of toxine which would be fatal to 4,000 pounds of living substance.

Flow of Water Through Submerged Pipes

AN investigation has been completed by the Engineering Experiment Station, University of Illinois, at Urbana under the direction of Fred B. Seely, Associate in Theoretical and Applied Mechanics, to determine the effects of mouthpieces upon the flow of water through a submerged short pipe. A knowledge of the extent of the loss of head due to contraction or expansion of a stream is of considerable importance in a variety of hydraulic problems. For example, it may be possible, through attention to the shape and angle of connections and intakes to increase the flow through the suction and discharge pipes of low head pumps, through large valves, through locomotive water columns, through the sluiceways of dams, through culverts and short tunnels, etc.

It is to be noted that losses of head due to contraction or expansion of a stream, which may in themselves be of relatively little consequence, may have a considerable influence upon subsequent losses because of the turbulent motion started by the contraction or expansion. A slight change in the conditions under which flow takes place may cause a large difference in the action or behavior of the water.

The experiments conducted by Mr. Seely involved the use of a cast iron pipe 22½ inches long and 6 inches in diameter, bored to a smooth surface. Cast iron conical mouthpieces of different lengths and angles were used. The laboratory tank employed was divided into two compartments by a vertical partition in which the short pipe was set in a horizontal position.

The results of the investigation are set forth in detail in Bulletin 96 of the Engineering Experiment Station, copies of which may be obtained gratis.

The Experiences of An Iron Atom—II*

The Cycle of Its Life History

By Charles R. Sturdevant[1]

Concluded from Scientific American Supplement No. 2192, Page 16, January 5, 1918

While this action was going on, our piece of spongy iron melted and trickled down between the pieces of incandescent coke, and fell through the layer of slag into a pool of molten iron which filled the bottom portion of the hearth.

It was during this final stage of my journey through the stack as part of a liquid drop of iron that I observed the source of that strong current of gas which had been constantly rushing up through the stack. Through the upper rim of the hearth were twelve 6-inch bronze pipes projecting an inch or so through the brick wall into the hearth, and streams of red-hot air, in all 37,000 cubic feet per minute, were constantly pouring into the furnace through these openings (tuyeres). As the oxygen portion of this air (21 per cent by volume) came in contact with the white-hot and porous coke, it penetrated each piece and united chemically with the carbon, thus liberating great quantities of heat. Each atom of oxygen combined ultimately with one of carbon, making carbon monoxide gas, this being the active reducing agent that robbed us of our oxygen. I watched the process and saw the coke pieces rapidly shrink and quickly disappear from sight, and I also saw the ash falling into the slag, with which it united and of which it became a part.

It was while trickling through the coke, and falling through the slag, that the drop of molten iron—of which I am a constituent part—became contaminated with several other elements. In fact all the drops of iron were affected likewise, and the mass of liquid metal as a whole absorbed by weight about 3.5 per cent of carbon; 1.25 per cent of silicon; 0.09 per cent phosphorus; 0.04 per cent of sulphur; and 1 per cent manganese. This means that in every 100 pounds of molten metal there were 3.5 pounds of pure carbon, 1.25 pounds of pure silicon, and so on. All of the metallic impurities present in the stock went into the iron. These foreign elements all being in solution were thoroughly mixed with the iron and were held in captivity by the iron atoms.

Pure iron, containing nothing but iron atoms like myself, can be produced only by laboratory processes. It has a white luster and is difficult to melt in any ordinary furnace (2,800 degrees Fahr.). It is very tough, malleable and ductile. The presence of 3.5 per cent to 4 per cent carbon changes the physical properties of iron completely, making it very brittle, more fusible and rendering it impossible to forge or weld. The principal product of the blast furnace is known as "pig iron"—commonly called "cast iron." This is the principal raw material for your whole iron industry and is now one of the great staples in the commerce of the world. The foundryman makes from it his cast iron kettle and stoves; the puddler in the past refined it and furnished the village blacksmith with wrought iron bars for chains and horseshoes; and the steelmaker now transforms it into rails or watch springs, fence wire or music wire, and a thousand other things.

After I had remained in this hearth for several hours an opening or "iron notch" was made through the lower edge of the wall, and the molten iron was permitted to escape and to flow down a trough into a large ladle mounted on a car or truck, carrying me along as a tiny part. Our ladle when filled was covered over with coke dust to prevent free access of oxygen, and also to prevent the rapid radiation of heat. We were then hauled to a Bessemer steel plant, where our ladle was bodily lifted to quite a height and we atoms were poured into a large barrel-shaped receptacle called a "mixer," which held some 1,000 tons of molten metal. We found it nearly full of pig iron. The whole mass was thoroughly mixed and made uniform in composition.

V

In which I am converted into Bessemer steel

I noticed that pig iron was often poured in on one side and out on the other side of the mixer. Finally I was caught in one of the outgoing streams and found myself in another ladle full of hot metal. This was drawn to the side of a Bessemer "converter." While waiting here to be weighed I noticed that the converter was a large, hollow, egg-shaped furnace mounted on two trunnions extending from its middle, and that it was lined with red-hot brick and had a lot of small holes through the bottom. At the time, it was on its side, and its big, open mouth was waiting to receive our charge of 15 tons of molten metal. We were quickly poured through a trough into the converter and then streams of air were forced through the small holes in the bottom. Being at 22 pounds pressure, the air came with a rush and a roar. The converter was immediately turned to an upright position and then began an excessively rapid series of molecular generations and disassociations that were full of interest—though the workmen on the outside could not see any of these actions and knew little about the wonderful changes that were taking place in our midst.

I was then uncombined and in a free state and, being liquid, had considerable freedom of motion among my neighbors. Ever since I had lost my oxygen companions in the blast furnace, I was very lonesome and was anxious to find others. But the silicon atoms were even more anxious for oxygen than we iron atoms were, and when the air came rushing up through our midst there was a grand rush and scramble for the oxygen atoms. I quickly united with one, and together we started for the top—the two of us (FeO) being much lighter than the iron. But we had not gone far before my new companion was forcibly wrenched from me by a silicon atom. They formed a stable molecule (SiO_2) which rose to the top of the charge and remained there as part of the slag. Some of the iron atoms were more fortunate than I and succeeded in reaching the top with their oxygen companions, where they remained along with the other oxides.

When I united with the oxygen I gave off a certain amount of heat. When the oxygen was wrenched from me an equal amount of heat was consumed—that is, it disappeared entirely as heat and became latent; it was in fact converted into an equivalent amount of work, just the amount needed to separate me from the oxygen atom. But when the silicon united with the oxygen more heat was liberated than was required to dissociate our molecule, resulting in a total temperature increase.

In three or four minutes practically all the silicon had been oxidized and had gone to the top. Before the last was burned, however, the manganese atoms in the same manner and for similar reasons were beginning to oxidize or burn to MnO molecules, and they too went to the top and mixed with the iron and silicon oxides already there. This thin layer of liquid oxides which formed on the top of the mass constituted the "slag." The silicon oxide or silica (SiO_2) neutralizes the other two oxides, and the three unite chemically. The quantity of the metal present in the converter had been reduced in weight by an amount exactly equal to the combined weight of the silicon, manganese and iron thus burned or oxidized.

Meanwhile the temperature of the mass had risen considerably, and when it attained a certain critical degree, the carbon atoms became very active and manifested an unusual avidity for oxygen. Prior to this time they had seemed rather indifferent. Now they united with all the oxygen present and even robbed me of a second oxygen atom I had managed to capture. Their union with the oxygen differed from that of the others in one respect. The new carbon monoxide molecules formed (CO) were so extremely active in their vibrations, and moved about with such extreme velocity, that they were separated from each other by several hundred diameters which placed each entirely beyond the other's influence or control. They constituted in fact a gas, and they escaped from the converter mouth as such, burning further into CO_2 as soon as they came into contact with the outside oxygen-carrying air, forming a long bluish flame. This gas formed so rapidly that it caused an intense boiling or agitation of the liquid mass, and I feared at one time that we would all be thrown out. But presently a little stream of water vapor was admitted along with the air and large quantities of heat disappeared as such in breaking down or dissociating the water molecules (H_2O) into their constituent gases, hydrogen and oxygen. This quieted the mass. Some of the phosphorus and sulphur were also oxidized during these actions, but as they rose to the surface they received such an unwelcome reception by the neutral slag that they were forced back into the iron, where they remained after giving up their oxygen.

This whole oxidizing process required only ten minutes of time. During this period nearly all of the silicon, manganese and carbon had been burned out, and a little iron. But not a single atom had been destroyed or annihilated. There were, however, a large number of iron oxide and carbon monoxide molecules which had not succeeded in gaining the top and were floating about in the mass of "blown" metal, enough were present in fact to make it valueless (hot short) as steel. To overcome this difficulty some crushed ferro-manganese (80 per cent manangese, 14 per cent iron, and 6 per cent carbon) was thrown into the ladle as the metal was being poured. This material quickly melted and the manganese promptly gathered up all the oxygen present and rose to the top as MnO. Coincident with this, enough carbon and manganese were added to the charge (replacing a part of that burned out) to give the composition of steel desired by the steelmaker who controlled this whole process.

During this oxidizing process the carbon had been reduced from 3.5 per cent to 0.09 per cent; the silicon from 1.25 per cent to a mere trace; and the manganese from 1 per cent to 0.45 per cent; and both the phosphorus and sulphur had been very slightly increased. (This is merely illustrative and it must not be supposed that all Bessemer steels have this exact composition.) By oxidizing out a portion of its foreign elements the brittle pig iron had been converted into a Bessemer steel which was very high in tensile strength, quite malleable and ductile, and which could be readily forged and welded.

And all these changes were giving me new and increasing economic values which were beginning to make me feel quite vain. While I remained in the ore bed as a part of the earth, I had no more value than so much dirt. The work and cost of digging me up and transporting me to the blast furnace gave me a valuation of $5.50 per ton. As pig iron I was worth $36.00 per ton; as Bessemer steel billets I was worth $65.00 per ton; and every conversion or transportation thereafter increased my utility and my selling price. And during all these changes not a human hand had touched me. Last year there were 39,000,000 tons of ingot steel made in the United States.

The ladle into which I had been poured along with the rest of the metal was swung around above a train of upright ingot molds, made of heavy cast iron. The liquid metal was run through an opening in the bottom of the ladle into mold after mold until all the metal had been poured or "teemed." Each ingot was about 20 inches square, 60 inches high, slightly tapering towards the top, and weighed about 6,000 pounds. As soon as the liquid metal came in contact with the thick cold walls of the mold it rapidly lost heat to the mold and the outer portion solidified. As the outer solidifying shell grew in thickness the rate of cooling of the inner liquid mass rapidly decreased, and this action permitted "segregation" to take place. By this I mean that many of those molecules which contained atoms of silicon, carbon, phosphorus, or sulphur—naturally migrated to the central liquid portion, which was the last to solidify or "freeze." This is because impure metallic compounds freeze at a lower temperature than do pure metals. In some manner which I don't clearly understand I became a part of a molecule containing both carbon and manganese atoms, and was one of the last to solidify. We were located in the upper central part of the ingot, just below the "pipe"—which I will now tell you about.

Metals occupy greater space or have greater volume when hot than when cold. Perhaps that is because we atoms and molecules vibrate more rapidly when hot, and require a little more room in consequence. The ingot shrinks as it cools, but since the outside is already solid, the only thing left for it to do is to form a cup-shaped cavity on top, where the last bit of molten metal solidifies. This depression or hollow space is called a "pipe," and sometimes it extends well down into the ingot. But with care in pouring, having the temperature just right and with the aid of further precautions, it can be held within reasonable limits.

*A paper read before the Cleveland Engineering Society, and published in its journal.

[1]American Steel & Wire Company, Worcester, Mass.

And I must tell you of another thing that happened while the ingot was cooling. While it was changing from the liquid to the solid state the metal formed into regular symmetrical crystals, and these grew in size very rapidly, and they continued to grow, small ones uniting to form large ones, until the temperature fell to about 1300 degrees Fahr., which is known as a critical temperature of steel. Since the interior portion cooled much more slowly than the rest, it contained much larger crystals.

Since each solid which crystallizes has its own characteristic form or structure, which it assumes if at all possible, and since these differ in general for the different elements found in steel, there was a fierce struggle among some of the elements in their efforts to dominate the others. The carbon in particular wanted to crystallize as flake graphite, but it could not divorce all of the iron, and as a final compromise all of the carbon present united chemically with just enough of the iron to form iron carbide (Fe_3C), and this substance arranged itself in microscopic sheets separated by thin sheets of nearly pure iron, the complex laminated structure as a whole being called "pearlite." This forms only when the metal cools slowly, and it always forms as the temperature falls through the critical range.

I noticed too that practically all of the phosphorus and sulphur in the crystal of which I was a part were forced by the iron to the boundary plains between crystals, forming an envelope of a weak iron compound about the crystal. This greatly weakened the cohesion between crystals. Had there been an excess of manganese present it would have united with most of the phosphorus and sulphur and the combination would have formed into little globules, thus strengthening the metal by removing the weak material between the crystal boundaries.

I should also mention one other phenomenon which took place in our ingot. As the molten metal was being teemed into the mold, gases and air were carried down with it, some of which, failing to escape, were caught in the metal and formed into "gas pockets." These did no especial harm unless located very near the surface.

In an hour or so after teeming we were moved to another department, where a special crane "stripped" the mold off of our ingot. We were then lifted into a "soaking pit" or furnace, where we remained an hour or more until the ingot had reached a uniform temperature throughout, suitable for "rolling."

From here we were conveyed to and placed upon a roll table, which carried us to a pair of heavy rolls, where we were sent back and forth between the rolls about 19 times. We were turned and moved about, the soft mass of metal being each time compressed and elongated until our stocky red-hot ingot had been changed into a long billet bar having a sectional area of 4 x 4 inches—and still red hot. This rolling crushed and broke up the large crystals into smaller ones, thus refining and strengthening the metal, and at the same time it closed up the inner gas pockets.

Our billet bar was moved along to power-driven shears, where it was cut into 42-inch billet lengths—the two defective ends being cut into short lengths and scrapped. Since I was imprisoned in one of these short pieces you will be interested in learning what became of it.

VI

IN WHICH I BECOME BASIC STEEL

I remained in a scrap pile for several days—just how many I do not know—until I was loaded into a small steel "charging box" along with other scrap. We were soon moved onto the charging floor in front of an open-hearth furnace. Our box was picked up by the long arm of a charging machine, pushed through one of the open furnace doors and dumped into the hearth on top of some limestone and a quantity of iron ore which had previously been placed there. More scrap was quickly introduced and then nearly an equal amount of pig iron. There were about 80 tons of material all told charged into the furnace.

I noticed that the furnace was rectangular in shape and looked from the outside like a baker's oven. It was about 35 feet long by 15 feet wide inside, lined throughout with red-hot firebrick, except the hearth, which was lined with a basic material which was not acted upon by the slag. The furnace had open port holes at each end, which were used alternately for the entrance of hot air and gas, and for the exit of the products of combustion.

When all the furnace doors had been closed an intensely hot flame of burning gas was caused to play over the charge. This soon began to melt the iron. I suspected that I was to pass through another refining process, so I said little but kept my eyes open to the many changes that were rapidly taking place.

As the pig iron began to melt, some of the iron was oxidized from the excess air in the flame, and when it had reached a molten state nearly all the silicon present had burned or oxidized into silica (SiO_2), most of the manganese had burned to manganese oxide (MnO) and some of the carbon to carbon monoxide (CO.) This latter, being a gas, passed out of the furnace. The other oxides floated on top as part of the slag. When all of the iron had melted, the limestone had been converted into lime, which had risen to the top, making the slag strongly basic in nature. This addition released from the slag a large share of the held iron oxide, permitting it to return to the charge where it gave up its oxygen to the other elements. Since the scrap had already been through at least one refining process, it contained less impurities than the pig iron. When therefore all of the iron and the scrap had melted, the impurities of the pig iron were in consequence greatly diluted.

The slag was now covering the steel, and it was difficult for the oxygen of the air to penetrate it and get to the metal underneath. To economize in time large chunks of rich iron ore were thrown into the furnace. These went through the slag into the molten metal, and while they were melting they gave up their oxygen to the phosphorus, to some of the sulphur and to nearly all the remaining carbon and manganese. The oxides of phosphorus and sulphur were held by the basic slag, so long as favorable temperature and slag conditions were maintained.

In this manner we rid ourselves of much of the so-called impurities in our midst, or of the foreign elements. In each case they were oxidized either from the air playing on top or from the iron ore introduced into the molten metal, and all these oxides automatically rose to the top and floated there as a slag—except carbon, which passed out of the furnace as gas. This process required eight hours of time, being much slower than the Bessemer process. Toward the last the workmen frequently introduced long-handled dippers and took out samples of iron or slag, after which they introduced certain materials, or changed the working temperature, and in that way controlled the quality of steel made.

As we were being poured out of the furnace into a large ladle, ferro-manganese was added to the charge for the same reasons it was added to the Bessemer ladle, *i. e.*, to remove the last trace of oxygen held in the charge and to add just the right amount of carbon and manganese to give the steel desired properties.

In this manner the materials charged into the furnace were converted into soft basic steel and slag. Since all the foreign elements present in the iron had been reduced to a very low percentage, the steel was correspondingly soft and malleable and ductile, as compared with the Bessemer steel. Yet we retained enough manganese to make it tough and workable. Since pure iron is soft and ductile you will have already observed that the qualities of hardness, toughness and strength so requisite to many grades of steel are obtained by adding very small percentages of these few elements about which we have been talking. Carbon alone when present in quantities greater than 0.3 of 1 per cent imparts to steel the very important added property of being hardened and tempered by heat treatment.

Again I was poured into an ingot mold, reheated in a soaking pit and converted into another billet in a blooming mill. In a few days our billet was taken to a rod mill, where it was first heated to bright redness, then rolled down into a long rod ¼-inch in diameter and automatically coiled. This coil was taken to a wire mill and prepared for wire drawing. Certain features of this process will, I trust, be of interest to you.

VII

IN WHICH I AM CONVERTED INTO A TELEGRAPH WIRE

Our rod while being made in the rod mill became covered with a thick, hard, black oxide scale (Fe_3O_4), which is chemically like pure magnetite iron ore. This had to be removed before the rod could be drawn through a die. While there were several ways in which this could have been done, the most effective was with the agency of sulphuric acid. So we were placed in a weak, hot solution of this acid and allowed to remain for about 15 minutes, during which the scale was removed.

A molecule of sulphuric acid consists of a combination of two atoms of hydrogen, one of sulphur and four of oxygen (H_2SO_4). When this is placed in a quantity of water, the molecule is partially broken down, *i. e.*, the hydrogen separates by itself and carries a positive charge of electricity. The other atoms (SO_4) remain combined and carry an equal negative charge. In all dilute solutions of mineral acids, similar separations invariably take place, and the more dilute the solution the more complete the separation of the acid molecules.

So when we were placed in the acid cleaning tub we found it filled with millions and millions of positively charged hydrogen molecules and with an equal number of negatively charged acid radical molecules. The former are the extremely active and powerful agents of all acids. When a piece of iron is introduced into such a solution, certain curious phenomena happen.

The charged hydrogen molecules will cause iron atoms to leave the surface of the iron and pass out into the solution. As each iron atom leaves the iron it takes on the positive charge of electricity from a hydrogen atom, and this action continues as long as there are any hydrogen atoms left to give up positive charges. So fresh acid had to be added to the solution at frequent intervals. Heating the solution accelerates this exchange action. If the iron be covered by a black porous scale the hydrogen will act less readily upon it than it will upon the iron underneath.

As the hydrogen loses its charge it becomes a gas and some will rise to the top and escape as gas and some will be absorbed or "occluded" by the iron. Under favorable circumstances steel will take up and hold sponge-like some 18 volumes of hydrogen gas. The latter enters the steel between the molecules or crystals and condenses on these interior surfaces. This makes the steel brittle (acid brittle) but does not greatly change its tensile strength. The gas forming under the scale helped to loosen it from the rod, causing it to drop to the bottom of the tub.

You will see that the chemical action is really an electrical one. It is caused by the fact that energy has in this exchange an opportunity of degrading itself or of "running down" a little, as it always does when possible. A little heat will be developed by the action and the iron atoms will hold the electrical charge more firmly than it was held by the hydrogen.

If you should take this liquid solution which had exchanged its hydrogen atoms for iron atoms and evaporate the water, the positive iron atoms would combine with the negative acid radical molecules (SO_4) and form iron sulphate ($FeSO_4$).

Since I was buried deep in the interior of the rod I was not affected by these chemical actions.

We were taken out of the acid tub and thoroughly washed to remove all traces of acid, then dipped into a tub of hot lime water. This was put on, I learned, to aid in lubrication. Had any acid remained on the wire surface, the basic lime would have converted the acid into gypsum which has a soapy consistency.

We were next placed in an oven where we remained for several hours at a temperature of about 300 degrees Fahr. This expelled the hydrogen gas from the steel and dried the lime. Our rod was next pointed, then threaded through a die and given three drafts to a No. 2 bright wire. The wire of which I was a part was then annealed, thoroughly cleaned in muriatic acid and washed in water, and drawn through a zinc chloride flux to remove from the wire all traces of oxide. Thence on through a galvanizing pan through a special wiping device. In this manner the wire was galvanized, i. e., it was given a smooth, uniform coating of zinc in order to prevent corrosion or rusting.

In the course of time after much handling and traveling about, our coil of wire was stretched on a pole line and attached to insulators and was later used as part of a long telegraph line. I shall never forget the sensations which I experienced when the first electrical current flowed through our wire, or my impression caused by the strange phenomena surrounding our wire. I was fortunately located on the surface of the wire where I could observe what was taking place both within and without the wire.

All the electrons in my interior were set into an entirely new and different kind of vibratory motion than they had ever experienced before in my normal unelectrified state. When an electric potential difference or voltage was applied to the ends of our line the negative electrons at the positive end of the line jumped out of the adjacent atoms or molecules leaving them positively electrified. These, in their turn, attracted more negative electrons out of the next layer of neutral atoms beyond and so on back to the negative end of the line until there was a complete bucket brigade formed by the atoms, the buckets being the negative electrons and the foremen being the nearly stationary atoms, which pass negative electricity along all the line.

While this method of current propagation may seem to you like a very complicated action you must remember that it has to do with the motion of the electrons which are extremely small and active, so active in fact that the current of electricity flows through a wire at nearly half the speed of light.

Energy was required to cause this unusual agitation of the electrons, and this was obtained from the generator. This energy was finally dissipated as heat. Thus every time a current was sent through our wire, heat was generated in it, the amount being directly proportional to the square of the current. For some unknown reason due to our atomic structure or arrangement, about eight times as much energy is required to force a given current through our steel wire as would be required to send the same current through a copper wire of similar dimensions—and also eight times as much heat would be developed in our wire.

I was interested in a curious phenomenon which always took place simultaneously with the flowing of a current. Strange to say, all of the ether surrounding our wire was instantly thrown into a circulatory motion about our wire as a center every time an electrical impulse passed through the line. The stronger the electrical current the greater the effect upon the ether surrounding our wire. Every time the current was reversed in direction there would instantly be a reversal in the rotational direction of the ether about the wire, showing plainly that the motion of the ether was dependent both in amount and direction upon the strength of the current flowing through the wire.

Had you, Mr. Man, placed a delicately suspended magnet near the wire in this ether flux, the magnet would have been affected by the ether. In fact, it would have aligned itself in the direction of the flowing ether in such manner that in every case it would enter the south pole of the magnet and leave the north pole. This shows very plainly that a wire carrying a current of electricity possesses magnetic properties to the extent of being surrounded by a magnetic field and that it can be transferred into mechanical work. Furthermore, I observed that every time the current and its resultant magnetic flux were altered either in direction or density the fluctuating magnetic field invariably induced an electric current in every conductor placed within the sphere of changing flux.

The magnetic effect of the current was due to the current itself flowing through the wire as already explained. The electrical pressure in the wire, even though no current were to flow also had its effect upon the surrounding ether, tending to send out rays of electrostatic flux radially from the center of the wire. Whenever the electric pressure is very high, this effect predominates and causes the so-called corona or luminous effects which have sometimes been observed in a poorly designed high potential transmission line. Both the magnetic and the electrostatic disturbances in the medium surrounding a wire are due to the peculiar nature of the vibrating electrons upon the ether in which they as well as the wire are immersed.

Owing to carelessness in handling, before I was suspended in the air a small flake of spelter located just above me had in some manner been chipped off the wire leaving me exposed to the air.

During the first rain storm a drop of water lodged on this exposed place and a peculiar action set up of which I will tell you. The zinc being a different metal from the iron was electro-positive to the iron, i. e., it was at a higher electrical potential than the iron which means that it would cause an electrical current to flow from the zinc through the water to the iron. And that is what happened. As the water spread over the surface connecting the two metals, the zinc atoms left the exposed zinc surface and went into solution, causing a local current to flow from the zinc to the iron through the water which served as an electrolyte, and back to the zinc through the wire.

As fast as the zinc atoms went into the water, they came into contact with oxygen atoms held in suspension and were oxidized forming zinc oxide. This in time would be washed away and lost in the earth. This action continued at intervals, whenever water was present, until there was a large exposed surface. Up to this time no action had taken place in the iron itself, for we iron atoms were protected by the "zone of influence" of the zinc. But when the exposed iron surface became so large that the zinc could protect it no longer, a corrosive action set up in the iron itself, which greatly affected me. Let me explain quite minutely how this action came about.

There were two exposed iron crystals differing in their chemical composition. One of them, the one I was in, was strongly electro-positive to the other. During a storm they became connected by water. Now this water, like all waters, had suffered slight decomposition. That is, a few of its molecules had dissociated giving positively charged hydrogen and negatively charged hydroxyl (HO) molecules. These were floating about in the water.

The negatively charged hydroxyl (HO) molecules collected about our positively charged metallic crystal, causing me, an atom of iron, and many others, to go into solution. I carried a positive charge of electricity with me. As I went into solution I neutralized two nearby negatively charged hydroxyl molecules and was united with them to form a ferrous hydroxide molecule —$Fe(OH)_2$. Coincident with this action a positively charged hydrogen atom gave up its charge to the negatively charged crystal, then escaped as a gas, causing a current of electricity to flow through the body of the metal back to the crystal which I left. And a little heat was developed.

Now all live water contains air in solution and when our ferrous hydroxide molecule came into contact with the oxygen of this suspended air we were changed to the ferric state and precipitated as red rust, Fe_2O_3.

To state it briefly, the iron atoms of our crystal were caused to dissolve in the water where they came into contact with oxygen and after passing through several successive intermediate actions finally were precipitated as red rust or pure hematite iron ore. This action continued as long as there were positively charged hydrogen atoms and oxygen and water. The absence of any one of these elements would have stopped the corrosive action. The presence of acids or salts in the water, or of strains in the iron, or of a more heterogeneous iron crystalline structure, would have accelerated the corrosive action.

And so I was finally changed back into an iron oxide, and as such one day I fell to the ground and became mixed with the earthly material in such a diffused state that I will probably never again become a part of an ore bed, or be permitted to serve any more useful purpose as a metal. Perhaps some day I may be absorbed by a root and taken up by the circulatory system of some plant or tree in which case I will pass through another cycle of changes, only to fall back to earth again as a last resting place.

The Virial Hypothesis and the Theory of the Brownian Movement

THE virial hypothesis is one of the oldest explanations of the average behavior of mechanical systems during prolonged periods of time. Since its presentation by Clausius it has been chiefly employed in the kinetic theory of gases for the establishment of the equation of state. Otherwise the virial hypothesis has played a restricted *rôle*. Recently Langevin [Abs. 823 (1908)] has given a very elegant proof of Einstein's formula for the average areal displacement of a Brownian particle, which depends upon a very similar assumption to that utilized by Clausius for the derivation of the virial hypothesis. Langevin's result, while admittedly skilful has been regarded by many physicists as not sufficiently rigid, and the present author here demonstrates that a fundamental relationship exists between the virial hypothesis and the Brownian movement. Langevin's result is therefore established. For this purpose the virial hypothesis is applied to movements which are no longer stationary, as is the case in the kinetic theory of gases. Stationary is described as the movement of a system when the coordinates and velocities of the material points always remain between finite limits and are independent of the time. After first establishing the validity limits of the virial hypothesis, it becomes apparent that important phenomena are no longer to be ascribed to Brownian particles on this hypothesis, and the author attempts to evolve a valid generalization. In conclusion a physical interpretation of the virial idea is discussed.—Note in *Science Abstracts* on an article by P. Frank in Ann. d. Physik.

The Relation Between Pressure-Gradient, Wind, and Friction in Steady Motion

ON the assumption that motion of the air near the earth's surface could be treated like the steady motion of a particle, Guldberg and Mohn developed simple equations connecting wind velocity with horizontal pressure gradient, latitude, air density and friction. In forming the equations it was assumed that friction acted in a direction opposed to that of the surface wind. Comparison with observations, however, showed that the equations were inapplicable to surface winds in the interior of continents, that coastal winds conformed more nearly with them, while observations at a single station at sea gave satisfactory agreement with them.

The author introduced the conception of friction acting in a direction different from that of the surface wind reversed, on the ground that the upper wind, which affects the surface wind by friction as well as the ground, usually differs in direction from that wind. Comparison with observations in Europe, America and over the North Atlantic give values of the angle between the direction of friction and the reversed direction of the surface wind which vary from thirty to sixty degrees and are slightly greater over sea than over land. Over land the angle appears to show a maximum in the early afternoon and a minimum at night.—Note in *Science Abstracts* on an article by F. Akerblom in Ark. för. Mat. Astron. och Fysik, Stockholm.

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